Appendix 2.1:
An exploration of alternative assessment models for Pacific cod in the eastern Bering Sea

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Introduction

This document represents an effort to respond to comments made by the BSAI Plan Team, the joint BSAI Plan Team, and the SSC on the 2012 assessment of the Pacific cod (*Gadus macrocephalus*) stock in the eastern Bering Sea (EBS, Thompson and Lauth 2012). Data are the same as in last year's assessment.

Comments from the Plan Teams and SSC

Responses to SSC and Plan Team Comments on Assessments in General

SSC minutes (June, 2012)

SSC1: "We note that stock assessment authors are free to develop and bring forward an alternative model or models in both the preliminary and final assessment." The authors spent considerable time developing their own alternative model for EBS Pacific cod this summer, but were unable to complete it in time for inclusion in this preliminary assessment. However, they have included Model 4 from last year's assessment, which was not one of the Teams' or SSC's requested models (see also comments JPT1 and SSC6).

SSC minutes (December, 2012)

SSC2: "The SSC recommends that the authors consider whether it is possible to estimate *M* with at least two significant digits in all future stock assessments to increase validity of the estimated OFL." The natural mortality rate *M* is reported to two significant digits in this preliminary assessment.

Joint Plan Team minutes (May, 2013)

JPT1: "For the last two years, the Teams have reserved the right to request that the author's preferred model be excluded from the final assessment. Upon further reflection and consideration of the SSC's June, 2012 minute stating that authors are free to include their own models in both the preliminary and final assessments, the Teams decided to abandon their previous policy. The Teams recommend that authors feel free to include their own models in both the preliminary and final assessments." See comment SSC1.

Responses to SSC and Plan Team Comments Specific to Eastern Bering Sea Pacific Cod

BSAI Plan Team minutes (September, 2012)

BPT1: "There was also a lot of interest in a model intermediate between Model 1 and Model 5, such as a version of Model 5 in which the commercial fishery data are still broken out by gear and season, with selectivity parameters estimated by time block. The Team recommends that the author investigate a model like that and bring it forward on his own if it looks worthwhile." (Note: Model 5 from last year's preliminary assessment was relabeled Model 4 in the final assessment.) This comment was considered by the Joint Plan Teams at their May 2013 meeting, at which time the Teams decided not to recommend such a model for inclusion in this preliminary assessment, a decision with which the SSC concurred (see also comments JPT2 and SSC6).

BPT2: "While they are not candidates for the specifications, we think that Models 1.1 and 4 provide a useful check on the candidate models and recommend that they be reported in November (and next September)." (Note: Models 1.1 and 4 from last year's preliminary assessment were relabeled Models 2 and 3 in the final assessment, respectively.) This comment was considered by the Joint Plan Teams at their May 2013 meeting, at which time the Teams decided not to recommend these models for inclusion in this preliminary assessment, a decision with which the SSC concurred (see also comments JPT2 and SSC6).

SSC minutes (October, 2012)

SSC2: "The Plan Team recommended the author bring forward a version of Model 5 that incorporates time varying selectivity for the fishery, if time permits and is worthwhile. The SSC supports Plan Team recommendations and encourages the author - if time permits - to bring forward a model that considers time varying survey *Q* to see if that produces better fit to the survey data." (Note: Model 5 from last year's preliminary assessment was relabeled Model 4 in the final assessment.) Time did not permit such a model to be included in last year's final assessment. This comment was considered by the Joint Plan Teams at their May 2013 meeting, at which time the Teams decided not to recommend such a model for inclusion in this preliminary assessment, a decision with which the SSC concurred (see also comments JPT2 and SSC6).

BSAI Plan Team minutes (November, 2012)

BPT3: "The Team recommends that jitter tests continue to be conducted, but statistics related to jitter tests do not need to be reported in future assessments." Jitter tests were conducted on all models presented here, but statistics relating to these tests are not reported.

SSC minutes (December, 2012)

SSC3: "The SSC re-iterates continuing concerns over the best value for the catchability coefficient, which by long-standing practice is either tuned to experimental results or fixed at a previously tuned value to keep it close to the experimental results (currently fixed at 0.77 in Model 1). Based on exploratory models estimating *Q*, catchability may be much higher. The SSC expects to receive a report prior to next year's assessment about a comparison of the standard EBS trawl with a high-opening trawl conducted during the 2012 field season." The requested report was attached to the minutes of the May 2013 Joint Plan Team meeting, and the SSC received a presentation on the results at its June 2013 meeting. Briefly, the results from this study failed to reject the null hypothesis that the nets used in the EBS and GOA surveys have the same catchability for Pacific cod in the 60-81 cm size range. However, as this was just a small pilot study, these results were not viewed as conclusive.

SSC4: "The results for Model 4 suggest that several of the new features represent an improvement over the current base model and the SSC recommends bringing forward a similar model next year that retains at least some of these promising features such as the Richards growth curve, newly parameterized seasonal changes in weight-at-length, selectivity modeled as a function of length, and estimating log-scale standard deviations for recruitment internally rather than fixing them." All of the listed features are included in all but one of the models presented here.

SSC5: "The SSC would like to see [an] … analysis of retrospective patterns for a model with an alternative estimate for *Q* (internally estimated or updated value from field experiment) in next year's assessment." Retrospective analyses were not conducted during this preliminary assessment. If at least one of the models requested for inclusion in the final assessment includes an alternative estimate of *Q*, the requested analysis will be conducted at that time.

Joint Plan Team minutes (May, 2013)

JPT2: "For the preliminary EBS assessment, the Teams recommend that the following models be included: 1. Last year's final model (Model 1), which is the same as the 2011 final model. 2. Last year's "exploratory" model (Model 4), but with the logarithm of survey catchability estimated internally, using a non-constraining uniform prior. 3. Last year's 'exploratory' model (Model 4), but with the logarithm of survey catchability estimated internally, using a normal prior derived from the archival tagging data used by Nichol et al. (2007), and with asymptotic trawl survey selectivity." The Teams' requested models are included in this preliminary assessment (see also comment SSC6).

SSC minutes (June, 2013)

SSC6: "The SSC concurs with author and Team's EBS model development for this coming year. The SSC recommends that model changes be kept to a minimum to ensure that we can track model sensitivities to specific changes in model structure. In addition to the recommended models, the assessment author reported that he will likely bring forward an EBS model similar to last year's Model 4, which the SSC supports. The SSC encourages the author to investigate annually changing fishery selectivity, for example modeled as a random walk process. The SSC concurs with the Team recommendation to discontinue models with no age data." The three models requested by the Teams and SSC are included in this preliminary assessment, along with Model 4 from last year's final assessment. One of the requested models is last year's accepted model (Model 1, also the same as the accepted model in 2011), which, by definition, keeps the number of model changes to a minimum. As noted in the response to comment SSC1, the authors spent considerable time developing their own alternative model for EBS Pacific cod this summer, but were unable to complete it in time for inclusion in this preliminary assessment. All models presented in this preliminary assessment include time-varying selectivity. In Model 1, selectivity changes between blocks of years. In Models 2-4, selectivity changes annually. All of the models include age data.

Model Structures

All of the models in this preliminary assessment were developed using Stock Synthesis (SS, Methot and Wetzel 2013). Stock Synthesis is programmed using the ADMB software package (Fournier et al. 2012).

All of the models in this preliminary assessment used a double-normal curve to model selectivity (SS selectivity-at-length pattern #24 for the fisheries in all models and for the survey in Models 2-4, and SS selectivity-at-age pattern #20 for the survey in Model 1). This functional form is constructed from two underlying and linearly rescaled normal distributions, with a horizontal line segment joining the two peaks. As configured in SS, the equation uses the following six parameters:

1. *beginning_of_peak_region* (where the curve first reaches a value of 1.0)
2. *width_of_peak_region* (where the curve first departs from a value of 1.0)
3. *ascending_width* (equal to twice the variance of the underlying normal distribution)
4. *descending_width* (equal to twice the variance of the underlying normal distribution)
5. *initial_selectivity* (at minimum length/age)
6. *final_selectivity* (at maximum length/age)

All but *beginning_of_peak_region* are transformed: The *ascending_width* and *descending_width* are log-transformed and the other three parameters are logit-transformed.

As requested by the Teams and SSC, Model 1 in this preliminary assessment is the same as last year's final model (coincidentally labeled Model 1 in the 2012 assessment), while Models 2 and 3 are based on last year's Model 4. Although not requested by the Teams or SSC, last year's Model 4 is also included here (again labeled Model 4). It will thus prove helpful to list the ways in which Model 4 differs from Model 1, which are as follow:

1. A new, inter- and intra-annually varying weight-length representation based on an explicit phenological process (Attachment 2.1, Annex 2.1.2 in Thompson and Lauth 2012) was used. Model 1 also used an intra-annually varying weight-length representation, but each set of seasonal parameters was estimated independently of the other seasons, without being constrained by any phenological process.
2. "Tail compression" was turned off. This feature aggregates size composition bins with few or zero data on a record-by-record basis, which improves computational speed, but which also makes some of the graphs in the R4SS package difficult to interpret. In Model 1, tail compression is turned on.
3. Fishery CPUE data were omitted. In Model 1, fishery CPUE data were included for purposes of comparison, but are not used in estimation.
4. A new population length bin was added for fish in the 0-0.5 cm range, which was used for extrapolating the length-at age curve below the first reference age. In Model 1, the lower bound of the first population length bin was 0.5 cm.
5. Mean-size-at-age data were eliminated. In Model 1, mean-size-at-age data were included, but not used in estimation.
6. The number of estimated year class strengths in the initial numbers-at-age vector was set at 10. In Model 1, only 3 elements of the initial numbers-at-age vector were estimated, which causes an automatic warning in SS.
7. The Richards growth equation (Richards 1959, Schnute 1981, Schnute and Richards 1990) was used, which adds one more parameter. In Model 1, the von Bertalanffy equation—a special case of the Richards equation—was used.
8. The log-scale standard deviation of recruitment was estimated internally (i.e., as a free parameter estimated by ADMB). In Model 1, this parameter was held constant at the value of 0.57 that was estimated in the final 2009 assessment by matching the standard deviation of the recruitment *dev*s, per Plan Team request.
9. Survey selectivity was modeled as a function of length. In Model 1, survey selectivity was modeled as a function of age.
10. Fisheries were defined with respect to each of the five seasons, but not with respect to gear. In Model 1, fisheries were defined with respect to both season and gear.
11. Fishery selectivity curves were defined for each of the five seasons, but were not stratified by gear type. In Model 1, seasons 1-2 and 4-5 were lumped into a pair of "super" seasons for the purpose of defining fishery selectivity curves, and fishery selectivities were also *gear*-specific (3 super-seasons × 3 gears = 9 selectivity curves).

12. The selectivity curve for the fishery that came closest to being asymptotic on its own (in this case, the season 3 fishery) was forced to be asymptotic by fixing both *width_of_peak_region* and *final_selectivity* at a value of 10.0 and *descending_width* at a value of 0.0. In Model 1, six of the nine super-season × gear fisheries were forced to exhibit asymptotic selectivity.
13. The age composition sample size multiplier was tuned iteratively to set the mean of the ratio of effective sample size to input sample size equal to 1.0. In Model 1, the variance adjustment was fixed at 1.0.
14. The two parameters governing the ascending limb of the survey selectivity schedule were given annual additive *dev*s with each σ_{dev} tuned to match the estimate that would be appropriate for a univariate linear-normal model with random effects integrated out (see Attachment 2.1, Annex 2.1.1 in Thompson and Lauth 2012). In Model 1, no *dev* vector corresponding to the *initial_selectivity* parameter was used, because it was "tuned out" in the 2009 final assessment; and σ_{dev} for the *ascending_width* parameter was left at the value of 0.07 estimated iteratively in the final 2009 assessment, per Plan Team request.
15. The logarithm of survey catchability (ln(*Q*)) was re-tuned iteratively to set the average of the product of *Q* and survey selectivity across the 60-81 cm range equal to 0.47, corresponding to the Nichol et al. (2007) estimate. In Model 1, *Q* was left at the value of 0.77 estimated by a similar procedure in the final 2009 assessment, per Plan Team request.

Last year's preliminary assessment also contained a set of nine "secondary" models that consisted of incremental transitional steps between last year's Model 1 and Model 4, so that the effects of the items in the above list could be examined almost one at a time.

The only differences between Models 2 and 3 in this preliminary assessment and Model 4 are with respect to point #15 in the above list:

- Model 2 estimates ln(*Q*) internally, using a non-constraining uniform prior distribution.
- Model 3 estimates ln(*Q*) internally, using a normal prior distribution derived from the archival tagging data used by Nichol et al. (2007), and with asymptotic trawl survey selectivity.

Because this preliminary assessment is only an exploration of alternative models, and in the interest of time, the iterative tuning procedures described in points #13 and 14 above were not redone for Models 2 and 3 (i.e., Models 2 and 3 used the tuned quantities from Model 4, rather than retuning those quantities individually for Models 2 and 3).

Discussion with Plan Team members indicated a preference for the normal prior distribution in Model 3 to be based on an analysis that used the 11 individual tags in the Nichol et al. (2007) study as fixed effects and that resulted in a prior mean close to ln(0.47) = -0.755. Evaluating the empirical cdf of each tag at 2.5 m (the height of the headrope used in the EBS shelf bottom trawl survey) and log transforming the resulting values gave a data set with a mean of -0.773 and a standard deviation of 0.461. The implied assumption of lognormality for *Q* was tested by comparing the likelihoods for lognormal, normal, logit-normal, and beta distributions (all evaluated at the maximum likelihood estimates of their respective parameters). Lognormal had the highest likelihood. The values μ_{lnQ} = -0.773 and σ_{lnQ} = 0.461 were therefore used as the mean and standard deviation of the normal prior distribution for ln(*Q*) in Model 3.

Development of the final versions of all models included calculation of the Hessian matrix. All models also passed a "jitter" test of 50 runs with a jitter parameter (equal to half the standard deviation of the logit-scale distribution from which initial values are drawn) of 0.01. In the event that a jitter run produced a better value for the objective function than the base run, then: 1) the model was re-run starting from the final parameter file from the best jitter run, 2) the resulting new control file became the new base run, and

3) the entire process (starting with a new set of jitter runs) was repeated until no jitter run produced a better value for the objective function than the most recent base run.

Except for *dev* parameters and the ln(*Q*) parameter in Model 3, all parameters were estimated with uniform prior distributions. Bounds were non-constraining in all cases, except for two selectivity parameters in Model 1 (*beginning_of_peak_region* was bound high for the August-December trawl fishery in the 1995-1999 time block, and *initial_selectivity* was bound low for the trawl survey; these results mean simply that the August-December trawl fishery in the 1995-1999 time block does not reach peak selectivity until the maximum age, and the trawl survey has a selectivity of zero for age zero fish).

Model 1 uses the same data file as last year's Model 1, while Models 2-4 use the same data file as last year's Model 4.

The software used to run Model 1 was SS V3.23b, as compiled on 11/5/2011, and the software used to run Models 2-4 was SS V3.24q, as compiled on 5/20/2013 (the most recent user manual is for SS V3.24f, Methot 2012).

Results

Overview

The following table summarizes the status of the stock as estimated by the four models ("Estimate" is the point estimate, "CV" is the ratio of the standard deviation to the point estimate, "SB(2012)" is female spawning biomass in 2012 (t), and "Bratio(2012)" is the ratio of SB(2012) to $B_{100\%}$):

	Model 1		Model 2		Model 3		Model 4	
	Estimate	CV	Estimate	CV	Estimate	CV	Estimate	CV
SB(2012)	689,032	0.056	300,957	0.086	269,901	0.081	824,483	0.061
Bratio(2012)	0.442	0.046	0.211	0.097	0.191	0.094	0.422	0.087

The estimates of both absolute and relative spawning biomass in 2012 are markedly higher in Models 1 and 4 (where *Q* is tuned to the results of Nichol et al. (2007)) than in Models 2 and 3 (where *Q* is estimated internally). The CVs associated with these estimates are all fairly small (<10%).

Here are the values of ln(*Q*) and *Q* resulting from each of the four models:

Parameter	Model 1	Model 2	Model 3	Model 4
ln(*Q*)	-0.26	0.32	0.24	-0.29
Q	0.77	1.37	1.27	0.75

Note that the *Q* values for Models 2 and 3 are 65-83% greater than the *Q* values for Models 1 and 4.

Goodness of Fit

Objective function values are shown for each model below (lower values are better, all else being equal; objective function components with a value less than 0.005 for all models are omitted for brevity; color scale extends from red (minimum) to green (maximum)):

Obj. func. component	Model 1	Model 2	Model 3	Model 4
Equilibrium catch	0.00	0.02	0.02	0.00
Survey abundance	-6.27	-23.35	-16.73	13.93
Length composition	4442.11	2506.14	2545.16	2565.36
Age composition	127.75	121.69	117.16	125.62
Recruitment	22.49	16.31	16.06	16.25
Priors	0.00	0.00	2.41	0.00
"Softbounds"	0.04	0.01	0.01	0.01
Parameter *devs*	19.54	20.43	21.41	19.90
Total	4605.66	2641.24	2685.51	2741.07

Note that the four models have different numbers of parameters: Model 1 has 184, Model 2 has 144, Model 3 has 141 (three fewer than Model 2 because of force asymptotic selectivity for the survey), and Model 4 has 143 (one fewer than Model 2 because *Q* is not estimated internally). Also, note that Models 2-4 use a different data file than Model 1 (different seasonal/gear structure, etc.).

The table below shows four statistics related to goodness of fit with respect to the survey abundance data (color scale extends from red (minimum) to green (maximum)). Relative values of the four statistics can be interpreted as follows: correlation—higher values indicate a better fit, root mean squared error—lower values indicate a better fit, average of standardized residuals—values closer to zero indicate a better fit, root mean squared standardized residual—values closer to unity indicate a fit more consistent with the sampling variability in the data.

Statistic	Model 1	Model 2	Model 3	Model 4
Correlation (observed:expected)	0.719	0.753	0.767	0.655
Root mean squared error	0.221	0.189	0.193	0.259
Average of standardized residuals	0.799	0.157	0.197	0.974
Root mean squared standardized residual	2.045	1.755	1.873	2.342

Model 3 fits the survey abundance data best by the first criterion, but Model 2 fits these data best by the other three criteria.

Figure 2.1.1 shows the fits of the four models to the trawl survey abundance data. The time trends are all qualitatively similar, especially Models 2 and 3. Model 2's estimates fall within the 95% confidence intervals of the survey estimates in 25 of the 31 years in the time series, compared to 23 years for Models 1, 3, and 4. All four models estimate a 2012 survey biomass lower than the observed value, although Model 1's estimate is very close to the observed value.

Table 2.1.1 shows the mean of the ratios between effective sample size and input sample size for the length composition data. All four models have average ratios much greater than unity for all fleets. Table 2.1.2 shows similar information for the age composition data, except that values are shown for each year rather than averaged across years. Model 1 has an average ratio of less than unity (0.86). Models 2-4 have average ratios just above unity, but this is because Model 4 (upon which Models 2 and 3 are based) downweights the age composition data by a factor of 0.85 precisely to achieve this result.

Figure 2.1.2 shows the four models' fits to the survey age composition data. Visually, it is difficult to discern much difference between these fits.

Parameter Estimates

Table 2.1.3 displays all of the parameters (except fishing mortality rates) estimated internally in any of the models (plus some parameters that are specified externally). Table 2.1.3a shows growth, recruitment (except annual *dev*s), initial fishing mortality, catchability, and initial age composition parameters as estimated internally by at least one of the models. Table 2.1.3b shows annual log-scale recruitment *dev*s as estimated by all of the models. These are plotted in Figure 2.1.3, where it is apparent that all models show a high degree of synchrony, particularly during the years covered by the survey. Table 2.1.3c shows main selectivity parameters as estimated by, or specified for, Model 1 (many of these parameter values get over-written by block-specific values). Table 2.1.3d shows block-specific selectivity parameters as estimated by Model 1. Table 2.1.3e shows selectivity parameter *dev*s as estimated by Model 1. Table 2.1.3f shows main selectivity parameters as estimated by, or specified for, Models 2-4. Table 2.1.3g shows selectivity *dev*s for survey selectivity parameter #3 as estimated by Models 2-4, and Table 2.1.3h shows selectivity *dev*s for survey selectivity parameter #5 as estimated by Models 2-4.

Values of externally estimated parameters (e.g., M = 0.34) are described by Thompson and Lauth (2012), and are not repeated here in the interest of brevity.

The parameter estimates in Table 2.1.3 imply the following values for the average of the product of catchability and survey selectivity across the 60-81 cm size range (these can be compared to the value of 0.47 obtained by Nichol et al. (2007)):

Model 1	Model 2	Model 3	Model 4
0.54	0.99	1.27	0.47

Table 2.1.4 shows estimates of full-selection fishing mortality for the four models (note that these are not counted as parameters in SS, and so do not have estimated standard deviations).

Estimates of Time Series

Figure 2.1.4 shows the time series of spawning biomass relative to $B_{100\%}$ as estimated by the four models (note that SS measures spawning biomass at the start of the year and uses a different estimator of mean recruitment than the AFSC's standard projection model). Major qualitative features are similar, but the scales are different, particularly when comparing Models 1 and 4 to Models 2 and 3. Model 1 peaks at a value of 0.94 in 1984, Model 2 peaks at a value of 0.55 in 1988, Model 3 peaks at a value of 0.44 in 1989, and Model 4 peaks at a value of 0.94 in 1985.

Figure 2.1.5 shows the time series of total (age 0+) biomass as estimated by the four models, with the trawl survey biomass estimates included for comparison. Models 1 and 4 estimate total biomasses much higher than observed by the survey, whereas the total biomass estimates from Models 2 and 3 are much closer to the survey observations.

Figure 2.1.6 shows fishery selectivity as estimated by the four models. Model 1's block-varying selectivity by season and gear clearly exhibits a more complicated pattern than the seasonal but year-invariant selectivity curves of Models 2-4. Except for the curve corresponding to season 3, which is constrained to be asymptotic in both Models 2-4, the selectivity curves for Model 3 all drop off more sharply at large sizes than those of Models 2 or 4.

Figure 2.1.7 shows time-varying trawl survey selectivity as estimated by the four models. The surfaces for the four models all show significant variability at the youngest/smallest ages/sizes, although these are hard to compare visually because age and length are not proportional. Models 1, 2, and 4, where selectivity at the oldest/largest ages/sizes is unconstrained, show significant declines past the age/size of peak selectivity. Model 3, in contrast, is constrained to exhibit asymptotic selectivity. The selectivities at the oldest/largest ages/sizes are 0.20, 0.33, 1.00, and 0.23 in Models 1, 2, 3, and 4 respectively.

Discussion

This exploration of alternative models confirms some of the findings of previous such explorations. One of these is that it is difficult to fit some of the data sets at levels consistent with the best estimates of their associated measurement errors. One data set that stands out in this regard is survey abundance.

As noted in last year's preliminary assessment (Attachment 2.1 in Thompson and Lauth 2012), it is difficult to imagine how the survey abundance data could be fit in a manner consistent with the reported sampling variability without allowing *Q* to vary, because the *inter*-annual variability in survey estimates relative to the *intra*-annual variability (standard errors) is so great. For example, the following tables show the relative year-to-year changes in survey estimates of numbers and biomass, together with the coefficients of variation, for every year in which the estimates of numbers or biomass increased by at least 85% over the previous year or decreased by at least 25% from the previous year (tables are sorted in order of increasing relative change):

Numbers				Biomass			
Change	Year	CV(current)	CV(previous)	Change	Year	CV(current)	CV(previous)
-0.43	2002	0.10	0.10	-0.32	1997	0.11	0.10
-0.42	1989	0.07	0.07	-0.27	1995	0.09	0.18
-0.39	1995	0.10	0.12	-0.26	2002	0.11	0.09
-0.35	2008	0.10	0.27	-0.26	1991	0.07	0.07
-0.30	1988	0.07	0.07	0.98	1994	0.18	0.08
0.86	2007	0.27	0.06	1.04	2010	0.12	0.08
1.04	2001	0.10	0.09				

On the other hand, unless the base value of *Q* is estimated internally, it seems likely that the primary effect of allowing time variability in catchability will be compensation for an overall lack of fit resulting from a constrained (or fixed) base value for ln(*Q*), rather than estimating true time variability.

Unfortunately, estimating the base value of *Q* internally continues to be a challenging proposition, as shown in several previous assessments and again here in Models 2 and 3. To date, none of the field experiments aimed at direct estimation of Pacific cod catchability in the EBS shelf bottom trawl survey have suggested that *Q* should exceed unity, yet both Models 2 and 3 estimate *Q* (with high precision) at values far in excess of unity (1.37 and 1.27, respectively, both with CVs of about 3 %).

Use of a prior distribution based on the data of Nichol et al. (2007) in Model 3 did little to constrain *Q* to a value more in line with what might be expected from the field experiments, although the influence of this prior distribution was confounded by Model 3's assumption of asymptotic selectivity for the survey. This confirms the result obtained in the 2009 assessment (Annex 2.1.1 in Thompson et al. 2009), where a random effects analysis was used to estimate the parameters of the prior distribution, as opposed to the fixed effects analysis used here in Model 3.

As noted in the response to Plan Team and SSC comments, the authors spent considerable time developing their own alternative model for EBS Pacific cod this summer, but were unable to complete it in time for inclusion in this preliminary assessment. The main features distinguishing this model from

Model 4 was use of SS selectivity-at-age pattern #17 (random walk with age) for both the fisheries and the survey, rather than the usual double-normal selectivity function. As with Model 4, *dev*s were allowed (potentially) for all selectivity parameters. A similar approach to selectivity was taken in this year's preliminary assessment of Pacific cod in the Aleutian Islands. In the interest of brevity, readers are referred to that document for further details. The major difference between the AI model and the EBS model was that the former was able to produce a positive definite Hessian matrix whereas the latter was not. Investigations to date have suggested a possible means to resolve this problem, so the EBS version of the model may be pursued in the future.

Another option that might be considered in the future is to omit seasonal structure from one or more models. The EBS Pacific cod models have been seasonally structured since the 1980s. Although this seasonal structure is helpful for reflecting intra-annual changes in fishing mortality and for capturing growth dynamics in this fast-growing species, it also makes examination of some other potential model features (such as time-varying parameters) difficult or impossible.

Acknowledgments

Dana Hanselman and the BSAI Groundfish Plan Team provided reviews of this preliminary assessment.

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Table 2.1.1a—Average input sample size and average ratio of effective sample size to input sample size for length composition data, Model 1.

Fleet	Mean input N	Mean Neff/Ninp
Jan-Apr Trawl Fishery	322.73	5.57
May-Jul Trawl Fishery	65.91	9.14
Aug-Dec Trawl Fishery	42.54	12.77
Jan-Apr Longline Fishery	467.76	8.88
May-Jul Longline Fishery	223.78	9.55
Aug-Dec Longline Fishery	671.07	6.70
Jan-Apr Pot Fishery	140.12	13.26
May-Jul Pot Fishery	139.81	18.03
Aug-Dec Pot Fishery	78.38	10.33
Post81 Shelf Survey	279.29	2.09

Table 2.1.1b—Average input sample size and average ratio of effective sample size to input sample size for length composition data, Models 2-4.

		Mean Neff/Ninp		
Fleet	Mean input N	Model 2	Model 3	Model 4
Season1 Fishery	326.41	7.37	7.19	7.83
Season2 Fishery	324.68	6.64	6.34	6.94
Season3 Fishery	122.91	8.06	8.06	8.09
Season4 Fishery	477.24	10.99	9.64	9.91
Season5 Fishery	324.39	8.36	8.20	8.78
Trawl Survey	225.16	3.38	3.02	3.26

Table 2.1.2—Input sample size and ratio of effective sample size to input sample size for each year of age composition data, all models. Note that Models 2-4 multiply the input sample size by 0.85, so the ratios between Model 1 and Models 2-4 are not directly comparable.

		Ratio of effective N to input N			
Year	Input N	Model 1	Model 2	Model 3	Model 4
1994	208	2.07	1.76	1.83	2.22
1995	174	0.20	0.18	0.19	0.23
1996	207	1.48	1.45	1.68	1.71
1997	209	0.81	2.08	2.22	1.15
1998	184	4.73	6.06	5.45	4.76
1999	250	0.51	0.40	0.32	0.39
2000	251	0.46	0.27	0.21	0.27
2001	276	0.40	0.18	0.21	0.24
2002	275	0.33	0.32	0.27	0.36
2003	395	0.74	2.29	1.42	1.32
2004	302	0.11	0.12	0.12	0.14
2005	372	1.39	1.19	0.66	2.37
2006	378	0.38	0.37	0.41	0.40
2007	419	0.18	0.24	0.20	0.33
2008	352	0.56	1.56	1.74	0.77
2009	410	0.21	0.29	0.32	0.32
2010	375	0.55	0.58	0.85	0.88
2011	364	0.31	0.16	0.20	0.25
Average:	300	0.86	1.08	1.02	1.01

Table 2.1.3a—Growth, recruitment (except devs), catchability, initial fishing mortality, and initial age composition devs as estimated by the four models ("Est." = point estimate, "SD" = standard deviation). Blanks indicate that the parameter in that row was not used by the model in that column, and "n/a" indicates that the parameter was used but not estimated (i.e., the parameter had a fixed value).

	Model 1		Model 2		Model 3		Model 4	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD
L_at_age01	1.41E+01	1.07E-01	1.39E+01	1.43E-01	1.38E+01	1.54E-01	1.38E+01	1.59E-01
L_at_age20	9.20E+01	5.33E-01	9.49E+01	1.24E+00	1.05E+02	2.43E+00	9.00E+01	8.78E-01
VonBert_K	2.43E-01	2.76E-03	2.95E-01	1.49E-02	2.07E-01	1.62E-02	2.85E-01	1.29E-02
Richards_growth			6.29E-01	5.94E-02	9.30E-01	6.63E-02	8.12E-01	5.81E-02
SD_of_length_at_age01	3.51E+00	6.94E-02	3.58E+00	8.50E-02	3.46E+00	8.61E-02	3.41E+00	8.47E-02
SD_of_length_at_age20	1.01E+01	1.66E-01	1.01E+01	2.65E-01	1.17E+01	4.38E-01	1.02E+01	2.12E-01
Ageing_bias_at_age01	3.41E-01	1.32E-02	2.75E-01	2.13E-02	2.99E-01	1.93E-02	3.33E-01	1.50E-02
Ageing_bias_at_age20	4.57E-01	1.60E-01	1.28E+00	2.14E-01	8.48E-01	2.01E-01	5.81E-01	1.83E-01
Log_mean_post76_recruits	1.32E+01	1.93E-02	1.30E+01	6.96E-02	1.29E+01	6.73E-02	1.34E+01	7.69E-02
SD_of_log_recruitment	5.70E-01	n/a	7.78E-01	8.26E-02	7.68E-01	8.23E-02	8.14E-01	9.14E-02
Pre1977_log_mean_offset	-1.20E+00	1.32E-01	-1.72E+00	1.16E-01	-1.73E+00	7.09E-02	-1.29E+00	2.16E-01
log_Q	-2.61E-01	n/a	3.16E-01	3.34E-02	2.40E-01	2.84E-02	-2.88E-01	n/a
Initial_F_Jan-Apr_trawl	6.71E-01	1.46E-01						
Initial_F_season1_fishery			3.82E+00	2.14E+00	6.80E+00	5.23E+00	7.06E-01	1.93E-01
Init_age10_dev			-6.85E-02	7.65E-01	-5.65E-03	7.67E-01	-4.68E-01	6.80E-01
Init_age09_dev			-1.26E-01	7.65E-01	-1.49E-02	7.66E-01	-5.76E-01	6.58E-01
Init_age08_dev			-2.15E-01	7.68E-01	-3.83E-02	7.73E-01	-6.76E-01	6.38E-01
Init_age07_dev			-3.25E-01	7.63E-01	-8.27E-02	8.07E-01	-7.35E-01	6.22E-01
Init_age06_dev			-3.78E-01	7.35E-01	-9.94E-02	8.63E-01	-6.97E-01	6.11E-01
Init_age05_dev			-2.85E-01	6.13E-01	-8.37E-02	7.15E-01	-5.35E-01	5.76E-01
Init_age04_dev			-7.00E-01	5.15E-01	-7.20E-01	5.14E-01	-5.79E-01	5.71E-01
Init_age03_dev	1.28E+00	1.89E-01	1.07E+00	2.04E-01	9.97E-01	1.67E-01	1.38E+00	2.54E-01
Init_age02_dev	-7.18E-01	4.18E-01	-2.79E-01	4.26E-01	-4.11E-01	4.25E-01	-3.89E-01	5.76E-01
Init_age01_dev	1.32E+00	2.17E-01	1.25E+00	2.18E-01	1.03E+00	2.00E-01	1.62E+00	2.69E-01

Table 2.1.3b—Recruitment *dev*s as estimated by the four models.

	Model 1		Model 2		Model 3		Model 4	
Parameter	Est.	SD	Est.	SD	Est.	SD	Est.	SD
Rec_dev1977	1.33E+00	1.08E-01	5.36E-01	1.45E-01	3.17E-01	1.40E-01	1.29E+00	1.44E-01
Rec_dev1978	4.77E-01	2.08E-01	9.24E-01	1.24E-01	7.26E-01	1.27E-01	1.06E+00	1.79E-01
Rec_dev1979	6.51E-01	1.11E-01	3.20E-01	1.41E-01	3.87E-01	1.27E-01	4.21E-01	1.83E-01
Rec_dev1980	-3.94E-01	1.33E-01	-4.80E-02	1.20E-01	-1.97E-01	1.30E-01	-2.66E-01	1.54E-01
Rec_dev1981	-9.95E-01	1.47E-01	-8.16E-01	1.52E-01	-8.88E-01	1.57E-01	-7.69E-01	1.61E-01
Rec_dev1982	9.55E-01	4.10E-02	8.32E-01	4.45E-02	8.21E-01	4.50E-02	9.15E-01	4.83E-02
Rec_dev1983	-5.66E-01	1.13E-01	-6.46E-01	1.23E-01	-7.44E-01	1.40E-01	-7.68E-01	1.50E-01
Rec_dev1984	7.46E-01	4.58E-02	7.35E-01	4.68E-02	7.54E-01	4.80E-02	7.25E-01	5.11E-02
Rec_dev1985	-9.43E-02	7.14E-02	1.65E-01	6.62E-02	1.65E-01	6.91E-02	8.59E-02	7.47E-02
Rec_dev1986	-8.56E-01	9.59E-02	-7.23E-01	1.05E-01	-6.57E-01	1.07E-01	-8.54E-01	1.18E-01
Rec_dev1987	-1.21E+00	1.12E-01	-7.82E-01	9.49E-02	-9.06E-01	1.13E-01	-1.30E+00	1.46E-01
Rec_dev1988	-2.65E-01	5.69E-02	-3.25E-01	6.67E-02	-2.68E-01	6.84E-02	-2.73E-01	7.08E-02
Rec_dev1989	5.04E-01	3.93E-02	4.08E-01	4.54E-02	4.10E-01	4.68E-02	3.73E-01	5.10E-02
Rec_dev1990	3.20E-01	4.44E-02	4.32E-01	4.69E-02	4.52E-01	4.81E-02	3.12E-01	5.42E-02
Rec_dev1991	-3.38E-01	6.23E-02	-2.28E-01	6.98E-02	-2.36E-01	7.45E-02	-4.10E-01	8.14E-02
Rec_dev1992	5.98E-01	3.20E-02	5.64E-01	3.55E-02	6.06E-01	3.60E-02	4.77E-01	3.94E-02
Rec_dev1993	-4.31E-01	5.80E-02	-3.00E-01	6.01E-02	-3.05E-01	6.32E-02	-5.24E-01	7.01E-02
Rec_dev1994	-3.59E-01	5.10E-02	-4.61E-01	5.46E-02	-4.27E-01	5.60E-02	-5.81E-01	6.34E-02
Rec_dev1995	-2.93E-01	5.44E-02	-5.23E-01	5.68E-02	-5.30E-01	5.98E-02	-5.60E-01	6.73E-02
Rec_dev1996	6.63E-01	3.18E-02	3.92E-01	3.51E-02	3.90E-01	3.57E-02	4.83E-01	3.76E-02
Rec_dev1997	-2.30E-01	5.10E-02	-9.14E-02	4.78E-02	-9.35E-02	4.89E-02	-1.91E-01	5.72E-02
Rec_dev1998	-2.69E-01	5.00E-02	-6.24E-02	4.99E-02	-8.71E-02	5.09E-02	-2.05E-01	5.95E-02
Rec_dev1999	4.36E-01	3.15E-02	5.51E-01	3.29E-02	5.98E-01	3.36E-02	5.56E-01	3.58E-02
Rec_dev2000	-3.33E-02	3.73E-02	2.52E-01	4.02E-02	2.56E-01	4.11E-02	9.08E-02	4.44E-02
Rec_dev2001	-8.42E-01	5.87E-02	-5.81E-01	5.76E-02	-5.48E-01	5.95E-02	-7.21E-01	6.82E-02
Rec_dev2002	-2.85E-01	3.92E-02	-3.03E-01	4.33E-02	-2.66E-01	4.47E-02	-3.04E-01	4.99E-02
Rec_dev2003	-4.78E-01	4.73E-02	-4.77E-01	4.88E-02	-4.50E-01	5.03E-02	-4.51E-01	5.77E-02
Rec_dev2004	-5.98E-01	5.31E-02	-5.38E-01	5.29E-02	-5.29E-01	5.39E-02	-4.90E-01	6.27E-02
Rec_dev2005	-4.69E-01	5.15E-02	-4.81E-01	5.33E-02	-4.86E-01	5.64E-02	-4.01E-01	6.75E-02
Rec_dev2006	8.43E-01	3.52E-02	6.84E-01	3.63E-02	7.28E-01	3.54E-02	8.79E-01	4.05E-02
Rec_dev2007	-3.60E-01	6.87E-02	-1.45E-01	7.00E-02	-1.48E-01	7.20E-02	-1.14E-01	8.04E-02
Rec_dev2008	1.17E+00	4.90E-02	8.75E-01	5.74E-02	9.71E-01	5.64E-02	1.09E+00	5.39E-02
Rec_dev2009	-1.02E+00	1.50E-01	-1.40E+00	1.58E-01	-1.35E+00	1.63E-01	-1.26E+00	1.70E-01
Rec_dev2010	6.25E-01	7.97E-02	3.70E-01	1.04E-01	5.01E-01	1.05E-01	5.89E-01	9.53E-02
Rec_dev2011	1.06E+00	1.27E-01	8.93E-01	1.61E-01	1.03E+00	1.65E-01	1.10E+00	1.53E-01

Table 2.1.3c—Main selectivity parameters as estimated by, or specified for, Model 1. Many of these parameter values get over-written by block-specific values (see Table 2.1.3d). Parameter codes:
Par1 = *beginning_of_peak_region* (where the curve first reaches a value of 1.0)
Par2 = *width_of_peak_region* (where the curve first departs from a value of 1.0)
Par3 = *ascending_width* (equal to twice the variance of the underlying normal distribution)
Par4 = *descending_width* (equal to twice the variance of the underlying normal distribution)
Par5 = *initial_selectivity* (at minimum length/age)
Par6 = *final_selectivity* (at maximum length/age)

Parameter	Est.	SD	Parameter	Est.	SD
Par1_Jan-Apr_Trawl	0	n/a	Par1_Aug-Dec_Longline	0	n/a
Par2_Jan-Apr_Trawl	0	n/a	Par2_Aug-Dec_Longline	-2.16E+00	2.74E-01
Par3_Jan-Apr_Trawl	0	n/a	Par3_Aug-Dec_Longline	0	n/a
Par4_Jan-Apr_Trawl	0	n/a	Par4_Aug-Dec_Longline	5.14E+00	3.28E-01
Par5_Jan-Apr_Trawl	-999	n/a	Par5_Aug-Dec_Longline	-999	n/a
Par6_Jan-Apr_Trawl	10	n/a	Par6_Aug-Dec_Longline	0	n/a
Par1_May-Jul_Trawl	0	n/a	Par1_Jan-Apr_Pot	0	n/a
Par2_May-Jul_Trawl	0	n/a	Par2_Jan-Apr_Pot	-9.29E+00	1.72E+01
Par3_May-Jul_Trawl	5.63E+00	1.03E-01	Par3_Jan-Apr_Pot	5.01E+00	4.97E-02
Par4_May-Jul_Trawl	0	n/a	Par4_Jan-Apr_Pot	4.44E+00	2.86E-01
Par5_May-Jul_Trawl	-999	n/a	Par5_Jan-Apr_Pot	-999	n/a
Par6_May-Jul_Trawl	10	n/a	Par6_Jan-Apr_Pot	0	n/a
Par1_Aug-Dec_Trawl	0	n/a	Par1_May-Jul_Pot	0	n/a
Par2_Aug-Dec_Trawl	0	n/a	Par2_May-Jul_Pot	0	n/a
Par3_Aug-Dec_Trawl	0	n/a	Par3_May-Jul_Pot	4.92E+00	8.21E-02
Par4_Aug-Dec_Trawl	0	n/a	Par4_May-Jul_Pot	0	n/a
Par5_Aug-Dec_Trawl	-999	n/a	Par5_May-Jul_Pot	-999	n/a
Par6_Aug-Dec_Trawl	10	n/a	Par6_May-Jul_Pot	10	n/a
Par1_Jan-Apr_Longline	0	n/a	Par1_Aug-Dec_Pot	0	n/a
Par2_Jan-Apr_Longline	-4.92E+00	2.12E+00	Par2_Aug-Dec_Pot	0	n/a
Par3_Jan-Apr_Longline	0	n/a	Par3_Aug-Dec_Pot	0	n/a
Par4_Jan-Apr_Longline	5.08E+00	1.41E-01	Par4_Aug-Dec_Pot	0	n/a
Par5_Jan-Apr_Longline	-999	n/a	Par5_Aug-Dec_Pot	-999	n/a
Par6_Jan-Apr_Longline	0	n/a	Par6_Aug-Dec_Pot	10	n/a
Par1_May-Jul_Longline	0	n/a	AgeSel_1_Survey	1.29E+00	6.18E-02
Par2_May-Jul_Longline	0	n/a	AgeSel_2_Survey	-3.75E+00	8.53E-01
Par3_May-Jul_Longline	5.01E+00	5.16E-02	AgeSel_3_Survey	-1.99E+00	4.55E-01
Par4_May-Jul_Longline	0	n/a	AgeSel_4_Survey	3.03E+00	3.07E-01
Par5_May-Jul_Longline	-999	n/a	AgeSel_5_Survey	-9.99E+00	4.25E-01
Par6_May-Jul_Longline	10	n/a	AgeSel_6_Survey	-1.38E+00	4.20E-01

Table 2.1.3d—Block-specific selectivity parameters as estimated by Model 1. Years indicate beginning of selectivity blocks.

Parameter	Est.	SD	Parameter	Est.	SD
Par1_Jan-Apr_Trawl_1977	6.89E+01	3.11E+00	Par6_Jan-Apr_Longline_1990	-4.99E-01	1.37E-01
Par1_Jan-Apr_Trawl_1985	7.64E+01	1.68E+00	Par6_Jan-Apr_Longline_1995	-7.17E-01	1.40E-01
Par1_Jan-Apr_Trawl_1990	6.86E+01	1.08E+00	Par6_Jan-Apr_Longline_2000	-1.19E+00	1.46E-01
Par1_Jan-Apr_Trawl_1995	7.38E+01	9.33E-01	Par6_Jan-Apr_Longline_2005	-9.46E-01	1.50E-01
Par1_Jan-Apr_Trawl_2000	7.82E+01	1.18E+00	Par1_May-Jul_Longline_1977	6.33E+01	2.22E+00
Par1_Jan-Apr_Trawl_2005	7.54E+01	8.42E-01	Par1_May-Jul_Longline_1980	6.24E+01	1.36E+00
Par3_Jan-Apr_Trawl_1977	6.17E+00	1.74E-01	Par1_May-Jul_Longline_1985	6.33E+01	1.12E+00
Par3_Jan-Apr_Trawl_1985	6.63E+00	7.64E-02	Par1_May-Jul_Longline_1990	6.35E+01	5.22E-01
Par3_Jan-Apr_Trawl_1990	6.07E+00	5.83E-02	Par1_May-Jul_Longline_2000	5.98E+01	5.62E-01
Par3_Jan-Apr_Trawl_1995	6.29E+00	4.60E-02	Par1_May-Jul_Longline_2005	6.44E+01	5.48E-01
Par3_Jan-Apr_Trawl_2000	6.30E+00	6.03E-02	Par1_Aug-Dec_Longline_1977	6.05E+01	2.17E+00
Par3_Jan-Apr_Trawl_2005	6.02E+00	5.07E-02	Par1_Aug-Dec_Longline_1980	6.97E+01	1.60E+00
Par1_May-Jul_Trawl_1977	5.03E+01	1.69E+00	Par1_Aug-Dec_Longline_1985	6.44E+01	7.53E-01
Par1_May-Jul_Trawl_1985	5.13E+01	1.74E+00	Par1_Aug-Dec_Longline_1990	6.70E+01	7.15E-01
Par1_May-Jul_Trawl_1990	6.19E+01	1.52E+00	Par1_Aug-Dec_Longline_1995	6.94E+01	6.92E-01
Par1_May-Jul_Trawl_2000	5.31E+01	1.50E+00	Par1_Aug-Dec_Longline_2000	6.36E+01	4.27E-01
Par1_May-Jul_Trawl_2005	5.87E+01	1.44E+00	Par1_Aug-Dec_Longline_2005	6.28E+01	3.94E-01
Par1_Aug-Dec_Trawl_1977	6.25E+01	3.99E+00	Par3_Aug-Dec_Longline_1977	4.52E+00	3.21E-01
Par1_Aug-Dec_Trawl_1980	8.19E+01	5.60E+00	Par3_Aug-Dec_Longline_1980	5.41E+00	1.34E-01
Par1_Aug-Dec_Trawl_1985	8.67E+01	5.33E+00	Par3_Aug-Dec_Longline_1985	4.88E+00	8.64E-02
Par1_Aug-Dec_Trawl_1990	4.56E+01	1.49E+01	Par3_Aug-Dec_Longline_1990	5.03E+00	7.57E-02
Par1_Aug-Dec_Trawl_1995	1.02E+02	9.41E-01	Par3_Aug-Dec_Longline_1995	5.50E+00	5.28E-02
Par1_Aug-Dec_Trawl_2000	5.74E+01	2.02E+00	Par3_Aug-Dec_Longline_2000	5.18E+00	4.10E-02
Par3_Aug-Dec_Trawl_1977	5.55E+00	3.27E-01	Par3_Aug-Dec_Longline_2005	4.94E+00	4.04E-02
Par3_Aug-Dec_Trawl_1980	6.66E+00	2.27E-01	Par6_Aug-Dec_Longline_1977	-2.65E+00	2.25E+00
Par3_Aug-Dec_Trawl_1985	6.61E+00	2.29E-01	Par6_Aug-Dec_Longline_1980	4.17E-01	7.67E-01
Par3_Aug-Dec_Trawl_1990	3.22E+00	4.26E+00	Par6_Aug-Dec_Longline_1985	2.06E-01	2.53E-01
Par3_Aug-Dec_Trawl_1995	7.02E+00	9.09E-02	Par6_Aug-Dec_Longline_1990	2.42E+00	8.88E-01
Par3_Aug-Dec_Trawl_2000	5.27E+00	2.04E-01	Par6_Aug-Dec_Longline_1995	9.45E+00	1.40E+01
Par1_Jan-Apr_Longline_1977	5.88E+01	2.07E+00	Par6_Aug-Dec_Longline_2000	-3.86E-01	1.93E-01
Par1_Jan-Apr_Longline_1980	7.24E+01	2.48E+00	Par6_Aug-Dec_Longline_2005	9.75E+00	7.03E+00
Par1_Jan-Apr_Longline_1985	7.52E+01	9.11E-01	Par1_Jan-Apr_Pot_1977	6.88E+01	9.18E-01
Par1_Jan-Apr_Longline_1990	6.60E+01	4.74E-01	Par1_Jan-Apr_Pot_1995	6.85E+01	5.50E-01
Par1_Jan-Apr_Longline_1995	6.57E+01	4.26E-01	Par1_Jan-Apr_Pot_2000	6.81E+01	5.21E-01
Par1_Jan-Apr_Longline_2000	6.35E+01	4.45E-01	Par1_Jan-Apr_Pot_2005	6.87E+01	5.20E-01
Par1_Jan-Apr_Longline_2005	6.74E+01	3.91E-01	Par6_Jan-Apr_Pot_1977	2.10E-01	5.52E-01
Par3_Jan-Apr_Longline_1977	5.14E+00	2.10E-01	Par6_Jan-Apr_Pot_1995	-2.60E-01	2.49E-01
Par3_Jan-Apr_Longline_1980	5.91E+00	1.79E-01	Par6_Jan-Apr_Pot_2000	-5.73E-01	2.35E-01
Par3_Jan-Apr_Longline_1985	5.86E+00	6.70E-02	Par6_Jan-Apr_Pot_2005	1.98E-01	2.31E-01
Par3_Jan-Apr_Longline_1990	5.22E+00	4.63E-02	Par1_May-Jul_Pot_1977	6.72E+01	8.57E-01
Par3_Jan-Apr_Longline_1995	5.30E+00	3.97E-02	Par1_May-Jul_Pot_1995	6.59E+01	7.21E-01
Par3_Jan-Apr_Longline_2000	5.36E+00	4.17E-02	Par1_Aug-Dec_Pot_1977	6.84E+01	1.17E+00
Par3_Jan-Apr_Longline_2005	5.34E+00	3.40E-02	Par1_Aug-Dec_Pot_2000	6.31E+01	7.08E-01
Par6_Jan-Apr_Longline_1977	-1.33E+00	7.98E-01	Par3_Aug-Dec_Pot_1977	5.19E+00	1.19E-01
Par6_Jan-Apr_Longline_1980	3.74E-01	1.06E+00	Par3_Aug-Dec_Pot_2000	4.54E+00	1.05E-01
Par6_Jan-Apr_Longline_1985	-1.28E+00	4.62E-01			

Table 2.1.3e—Selectivity parameter *dev*s as estimated by Model 1.

Parameter	Est.	SD
Par3_Survey_dev1982	-4.93E-02	3.42E-02
Par3_Survey_dev1983	-5.64E-02	1.68E-02
Par3_Survey_dev1984	-9.14E-02	2.76E-02
Par3_Survey_dev1985	-1.25E-02	2.06E-02
Par3_Survey_dev1986	-6.03E-02	2.24E-02
Par3_Survey_dev1987	2.54E-02	4.20E-02
Par3_Survey_dev1988	-8.39E-02	3.27E-02
Par3_Survey_dev1989	-1.29E-01	1.81E-02
Par3_Survey_dev1990	-4.44E-02	2.04E-02
Par3_Survey_dev1991	-5.61E-02	2.17E-02
Par3_Survey_dev1992	7.72E-02	4.17E-02
Par3_Survey_dev1993	3.53E-02	2.93E-02
Par3_Survey_dev1994	-5.53E-02	2.12E-02
Par3_Survey_dev1995	-1.05E-01	1.92E-02
Par3_Survey_dev1996	-1.26E-01	1.73E-02
Par3_Survey_dev1997	-8.12E-02	1.47E-02
Par3_Survey_dev1998	-8.84E-02	1.85E-02
Par3_Survey_dev1999	-9.13E-02	1.70E-02
Par3_Survey_dev2000	-5.48E-02	1.53E-02
Par3_Survey_dev2001	1.37E-01	3.70E-02
Par3_Survey_dev2002	-2.99E-02	2.33E-02
Par3_Survey_dev2003	-1.72E-02	1.88E-02
Par3_Survey_dev2004	-3.85E-02	1.87E-02
Par3_Survey_dev2005	2.31E-02	2.52E-02
Par3_Survey_dev2006	1.30E-01	3.73E-02
Par3_Survey_dev2007	1.81E-01	3.73E-02
Par3_Survey_dev2008	9.77E-02	3.76E-02
Par3_Survey_dev2009	-3.02E-03	1.68E-02
Par3_Survey_dev2010	-1.48E-02	3.55E-02

Table 2.1.3f—Main selectivity parameters as estimated by Models 2-4.

	Model 2		Model 3		Model 4	
Parameter	Est.	SD	Est.	SD	Est.	SD
Par1_Season1	7.10E+01	4.84E-01	7.26E+01	4.83E-01	6.89E+01	4.94E-01
Par2_Season1	-9.49E+00	1.32E+01	-9.61E+00	1.06E+01	-9.43E+00	1.44E+01
Par3_Season1	5.76E+00	3.07E-02	5.80E+00	2.92E-02	5.71E+00	3.30E-02
Par4_Season1	5.06E+00	3.13E-01	6.05E+00	4.24E-01	5.02E+00	2.23E-01
Par5_Season1	-999	n/a	-999	n/a	-999	n/a
Par6_Season1	-4.23E-02	2.14E-01	-1.04E+00	7.21E-01	-2.24E-01	1.59E-01
Par1_Season2	7.15E+01	5.57E-01	7.35E+01	5.74E-01	6.91E+01	5.75E-01
Par2_Season2	-9.51E+00	1.28E+01	-9.57E+00	1.14E+01	-9.36E+00	1.59E+01
Par3_Season2	5.96E+00	3.10E-02	6.00E+00	2.96E-02	5.91E+00	3.40E-02
Par4_Season2	4.77E+00	4.42E-01	6.84E+00	4.38E-01	4.77E+00	2.82E-01
Par5_Season2	-999	n/a	-999	n/a	-999	n/a
Par6_Season2	4.05E-01	2.25E-01	-2.20E+00	1.54E+00	1.65E-01	1.58E-01
Par1_Season3	6.91E+01	7.43E-01	7.16E+01	7.75E-01	6.61E+01	7.49E-01
Par2_Season3	10	n/a	10	n/a	10	n/a
Par3_Season3	5.77E+00	4.93E-02	5.85E+00	4.75E-02	5.70E+00	5.37E-02
Par4_Season3	0	n/a	0	n/a	0	n/a
Par5_Season3	-999	n/a	-999	n/a	-999	n/a
Par6_Season3	10	n/a	10	n/a	10	n/a
Par1_Season4	6.67E+01	4.56E-01	6.92E+01	4.65E-01	6.45E+01	4.25E-01
Par2_Season4	8.31E-01	5.04E-01	4.24E-01	2.45E-01	-1.78E+00	3.28E-01
Par3_Season4	5.21E+00	3.69E-02	5.35E+00	3.36E-02	5.10E+00	3.86E-02
Par4_Season4	3.66E+00	3.32E+00	4.47E+00	9.95E-01	1.53E+00	2.21E+00
Par5_Season4	-999	n/a	-999	n/a	-999	n/a
Par6_Season4	-1.17E-01	1.78E+00	-1.95E+00	1.44E+00	2.07E+00	3.25E-01
Par1_Season5	6.61E+01	5.36E-01	6.84E+01	5.51E-01	6.36E+01	5.42E-01
Par2_Season5	-1.85E+00	5.64E-01	-1.79E+00	5.31E-01	-1.97E+00	4.52E-01
Par3_Season5	5.30E+00	4.38E-02	5.42E+00	4.06E-02	5.17E+00	4.91E-02
Par4_Season5	5.42E+00	1.08E+00	7.17E+00	7.49E-01	5.10E+00	6.41E-01
Par5_Season5	-999	n/a	-999	n/a	-999	n/a
Par6_Season5	3.40E-01	5.75E-01	-3.67E+00	4.95E+00	2.68E-01	2.71E-01
Par1_Survey	3.46E+01	7.74E-01	2.98E+01	5.87E-01	2.74E+01	1.17E+00
Par2_Survey	-8.93E+00	2.38E+01	10	n/a	-1.52572	0.184293
Par3_Survey	5.68E+00	3.83E-01	4.63E+00	4.64E-01	4.04E+00	4.77E-01
Par4_Survey	7.64E+00	4.00E-01	10	n/a	6.7493	0.271094
Par5_Survey	-9.91E-01	3.03E-01	-5.48E-01	2.54E-01	-3.96E-01	2.16E-01
Par6_Survey	-7.21E-01	5.61E-01	10	n/a	-1.1843	0.328352

Table 2.1.3g—Selectivity *dev*s for survey selectivity parameter #3 as estimated by Models 2-4.

	Model 2		Model 3		Model 4	
Parameter	Est.	SD	Est.	SD	Est.	SD
Par3_Survey_dev1982	-3.15E+00	6.85E-01	-3.75E+00	1.24E+00	-3.08E+00	1.42E+00
Par3_Survey_dev1983	-2.38E+00	6.63E-01	-2.75E+00	1.05E+00	-2.99E+00	1.18E+00
Par3_Survey_dev1984	-4.51E-01	4.75E-01	-2.94E-01	5.82E-01	-3.78E-01	5.97E-01
Par3_Survey_dev1985	1.48E-01	4.09E-01	4.55E-01	4.72E-01	5.98E-01	4.18E-01
Par3_Survey_dev1986	-1.02E+00	4.51E-01	-1.23E+00	5.41E-01	-1.59E+00	6.41E-01
Par3_Survey_dev1987	-1.31E-02	5.96E-01	4.38E-01	6.39E-01	9.24E-01	7.17E-01
Par3_Survey_dev1988	-9.14E-01	4.79E-01	-6.15E-01	6.22E-01	-3.01E-01	7.57E-01
Par3_Survey_dev1989	-5.33E+00	1.02E+00	-4.30E+00	1.53E+00	-2.70E+00	1.32E+00
Par3_Survey_dev1990	-1.93E+00	7.58E-01	-1.85E+00	9.96E-01	-1.78E+00	1.11E+00
Par3_Survey_dev1991	-1.18E+00	5.56E-01	-1.07E+00	7.34E-01	-9.43E-01	8.29E-01
Par3_Survey_dev1992	1.15E+00	1.03E+00	1.38E+00	9.55E-01	1.68E+00	1.01E+00
Par3_Survey_dev1993	1.04E+00	9.50E-01	1.23E+00	8.78E-01	1.47E+00	8.98E-01
Par3_Survey_dev1994	-3.92E-01	4.64E-01	-1.48E-02	5.82E-01	2.40E-01	5.78E-01
Par3_Survey_dev1995	-6.36E-01	4.48E-01	-4.60E-01	5.95E-01	-3.61E-01	6.29E-01
Par3_Survey_dev1996	-1.04E+00	5.15E-01	-8.76E-01	8.89E-01	-8.55E-01	8.57E-01
Par3_Survey_dev1997	-6.29E-01	5.15E-01	-1.52E-01	5.56E-01	-3.02E-01	4.91E-01
Par3_Survey_dev1998	-1.15E+00	4.46E-01	-1.49E+00	5.68E-01	-2.08E+00	8.10E-01
Par3_Survey_dev1999	-1.39E+00	4.43E-01	-1.30E+00	5.55E-01	-1.37E+00	6.10E-01
Par3_Survey_dev2000	-2.86E+00	6.25E-01	-3.11E+00	8.97E-01	-3.29E+00	1.05E+00
Par3_Survey_dev2001	1.42E+00	8.39E-01	1.81E+00	7.85E-01	2.26E+00	8.81E-01
Par3_Survey_dev2002	-2.04E+00	5.37E-01	-2.69E+00	8.78E-01	-2.68E+00	1.19E+00
Par3_Survey_dev2003	4.72E-01	5.03E-01	8.35E-01	5.41E-01	8.32E-01	4.65E-01
Par3_Survey_dev2004	-2.32E-01	5.87E-01	3.43E-01	5.86E-01	4.44E-01	5.41E-01
Par3_Survey_dev2005	7.59E-01	5.40E-01	1.09E+00	5.60E-01	9.38E-01	4.41E-01
Par3_Survey_dev2006	-3.85E+00	1.06E+00	-2.81E+00	1.74E+00	-1.75E+00	2.17E+00
Par3_Survey_dev2007	1.52E+00	1.50E+00	2.01E+00	1.40E+00	2.22E+00	1.39E+00
Par3_Survey_dev2008	-1.17E+00	5.58E-01	-1.26E+00	6.62E-01	-1.68E+00	8.53E-01
Par3_Survey_dev2009	-1.64E+00	5.11E-01	-1.94E+00	7.33E-01	-2.37E+00	9.52E-01
Par3_Survey_dev2010	-1.02E-01	1.29E+00	-1.01E+00	1.07E+00	-1.35E+00	1.26E+00

Table 2.1.3h—Selectivity *dev*s for survey selectivity parameter #5 as estimated by Models 2-4.

	Model 2		Model 3		Model 4	
Parameter	Est.	SD	Est.	SD	Est.	SD
Par5_Survey_dev1982	-4.46E-01	4.54E-01	-5.54E-01	4.59E-01	-6.49E-01	4.75E-01
Par5_Survey_dev1983	2.17E-01	3.55E-01	-6.26E-02	3.24E-01	-1.58E-01	3.00E-01
Par5_Survey_dev1984	-8.63E-01	7.43E-01	-7.97E-01	6.20E-01	-7.67E-01	5.77E-01
Par5_Survey_dev1985	-1.76E+00	7.71E-01	-1.82E+00	7.04E-01	-1.67E+00	6.61E-01
Par5_Survey_dev1986	-3.79E-01	4.29E-01	-6.02E-01	3.72E-01	-6.25E-01	3.56E-01
Par5_Survey_dev1987	-7.37E-01	9.73E-01	-9.24E-01	9.20E-01	-6.90E-01	9.99E-01
Par5_Survey_dev1988	-1.36E+00	7.26E-01	-1.38E+00	6.64E-01	-9.96E-01	7.27E-01
Par5_Survey_dev1989	-1.10E+00	3.89E-01	-1.40E+00	3.72E-01	-1.48E+00	3.60E-01
Par5_Survey_dev1990	2.55E-01	3.82E-01	1.03E-02	3.60E-01	6.74E-02	3.50E-01
Par5_Survey_dev1991	-2.63E-01	4.36E-01	-4.69E-01	3.87E-01	-3.91E-01	3.83E-01
Par5_Survey_dev1992	-4.69E-01	1.02E+00	-4.72E-01	1.04E+00	-2.81E-01	1.10E+00
Par5_Survey_dev1993	-4.79E-01	9.87E-01	-5.04E-01	9.96E-01	-4.22E-01	1.02E+00
Par5_Survey_dev1994	-1.04E+00	8.11E-01	-1.07E+00	7.61E-01	-1.06E+00	7.56E-01
Par5_Survey_dev1995	-1.27E+00	7.32E-01	-1.28E+00	6.23E-01	-1.26E+00	5.97E-01
Par5_Survey_dev1996	-1.23E+00	6.43E-01	-1.26E+00	6.09E-01	-1.52E+00	5.42E-01
Par5_Survey_dev1997	-7.39E-01	6.65E-01	-9.36E-01	5.65E-01	-1.13E+00	4.00E-01
Par5_Survey_dev1998	-9.42E-01	4.36E-01	-1.07E+00	3.52E-01	-1.03E+00	3.31E-01
Par5_Survey_dev1999	-9.24E-01	3.90E-01	-1.15E+00	3.44E-01	-1.11E+00	3.24E-01
Par5_Survey_dev2000	-1.80E-01	3.31E-01	-4.93E-01	2.91E-01	-5.60E-01	2.63E-01
Par5_Survey_dev2001	-9.38E-01	9.07E-01	-1.06E+00	8.95E-01	-8.11E-01	9.42E-01
Par5_Survey_dev2002	9.06E-02	3.77E-01	-1.78E-01	3.48E-01	-9.36E-02	3.47E-01
Par5_Survey_dev2003	-1.10E+00	8.89E-01	-1.22E+00	8.56E-01	-1.35E+00	8.11E-01
Par5_Survey_dev2004	-6.38E-01	9.71E-01	-9.54E-01	8.61E-01	-1.11E+00	7.92E-01
Par5_Survey_dev2005	-1.34E+00	8.63E-01	-1.37E+00	8.55E-01	-1.61E+00	8.05E-01
Par5_Survey_dev2006	1.68E+00	3.92E-01	2.01E+00	5.22E-01	1.85E+00	5.32E-01
Par5_Survey_dev2007	3.18E+00	6.93E-01	2.95E+00	7.21E-01	2.59E+00	7.65E-01
Par5_Survey_dev2008	1.03E+00	4.01E-01	8.72E-01	3.86E-01	9.12E-01	3.95E-01
Par5_Survey_dev2009	1.30E+00	3.66E-01	8.73E-01	3.23E-01	7.28E-01	2.94E-01
Par5_Survey_dev2010	2.93E-01	1.19E+00	5.77E-01	5.73E-01	5.38E-01	5.74E-01

Table 2.1.4a— Estimates of seasonal full-selection fishing mortality rates, expressed on an annual time scale (Model 1). Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Jul, Sea4=Aug-Oct, Sea5=Nov-Dec. Rates have been multiplied by relative season length before summing to get total.

	Trawl fishery					Longline fishery					Pot fishery					
Year	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Sea1	Sea2	Sea3	Sea4	Sea5	Total
1977	0.087	0.090	0.056	0.049	0.043	0.017	0.017	0.006	0.024	0.032	0	0	0	0	0	0.081
1978	0.099	0.103	0.067	0.057	0.050	0.017	0.017	0.006	0.026	0.035	0	0	0	0	0	0.093
1979	0.072	0.074	0.044	0.040	0.034	0.013	0.013	0.005	0.019	0.025	0	0	0	0	0	0.066
1980	0.064	0.063	0.031	0.042	0.035	0.010	0.010	0.004	0.014	0.017	0	0	0	0	0	0.056
1981	0.034	0.033	0.032	0.064	0.061	0.004	0.004	0.002	0.009	0.011	0	0	0	0	0	0.051
1982	0.035	0.035	0.036	0.045	0.036	0.001	0.001	0.001	0.004	0.005	0	0	0	0	0	0.040
1983	0.054	0.057	0.051	0.053	0.044	0.005	0.005	0.003	0.004	0.005	0	0	0	0	0	0.056
1984	0.062	0.066	0.057	0.056	0.049	0.007	0.008	0.006	0.028	0.038	0	0	0	0	0	0.075
1985	0.078	0.084	0.066	0.065	0.051	0.024	0.026	0.010	0.034	0.047	0	0	0	0	0	0.096
1986	0.088	0.093	0.066	0.065	0.053	0.017	0.019	0.005	0.027	0.038	0	0	0	0	0	0.092
1987	0.096	0.103	0.052	0.053	0.052	0.042	0.045	0.013	0.042	0.060	0	0	0	0	0	0.107
1988	0.194	0.209	0.101	0.113	0.120	0.001	0.001	0.002	0.003	0.004	0	0	0	0	0	0.143
1989	0.206	0.224	0.098	0.059	0.054	0.008	0.009	0.012	0.015	0.013	0.000	0.000	0.000	0.000	0.000	0.132
1990	0.174	0.191	0.092	0.029	0.025	0.031	0.034	0.047	0.051	0.047	0.000	0.000	0.002	0.002	0.001	0.139
1991	0.179	0.378	0.067	0.048	0.000	0.061	0.105	0.087	0.099	0.108	0.000	0.000	0.002	0.010	0.004	0.217
1992	0.147	0.223	0.055	0.033	0.010	0.133	0.240	0.141	0.091	0.000	0.000	0.002	0.030	0.011	0.000	0.216
1993	0.187	0.256	0.028	0.037	0.011	0.223	0.229	0.027	0.000	0.000	0.000	0.011	0.006	0.000	0.000	0.177
1994	0.085	0.293	0.019	0.075	0.014	0.188	0.263	0.029	0.103	0.000	0.000	0.031	0.009	0.016	0.000	0.208
1995	0.210	0.422	0.005	0.193	0.002	0.241	0.308	0.020	0.106	0.057	0.001	0.076	0.039	0.015	0.010	0.316
1996	0.141	0.367	0.037	0.105	0.021	0.235	0.260	0.018	0.118	0.023	0.000	0.126	0.054	0.022	0.005	0.285
1997	0.175	0.396	0.024	0.097	0.024	0.262	0.279	0.042	0.113	0.193	0.000	0.097	0.040	0.020	0.005	0.323
1998	0.122	0.224	0.022	0.136	0.016	0.287	0.208	0.023	0.093	0.116	0.000	0.062	0.034	0.011	0.000	0.252
1999	0.147	0.214	0.016	0.063	0.004	0.329	0.236	0.019	0.121	0.042	0.000	0.062	0.034	0.013	0.000	0.239
2000	0.164	0.215	0.019	0.027	0.003	0.291	0.081	0.008	0.126	0.136	0.132	0.049	0.000	0.001	0.000	0.223
2001	0.068	0.116	0.015	0.035	0.005	0.165	0.148	0.018	0.156	0.149	0.001	0.114	0.003	0.018	0.004	0.190
2002	0.103	0.174	0.031	0.035	0.002	0.307	0.137	0.008	0.184	0.110	0.018	0.087	0.005	0.015	0.006	0.226
2003	0.126	0.136	0.028	0.031	0.000	0.312	0.161	0.013	0.183	0.137	0.136	0.018	0.000	0.024	0.010	0.243
2004	0.169	0.146	0.041	0.038	0.000	0.328	0.159	0.013	0.171	0.165	0.088	0.030	0.005	0.019	0.004	0.254
2005	0.223	0.136	0.036	0.014	0.001	0.455	0.071	0.020	0.191	0.167	0.087	0.033	0.000	0.025	0.003	0.268
2006	0.267	0.146	0.036	0.025	0.000	0.521	0.078	0.013	0.267	0.009	0.121	0.042	0.002	0.025	0.008	0.291
2007	0.169	0.194	0.066	0.020	0.001	0.568	0.028	0.009	0.213	0.008	0.140	0.017	0.004	0.036	0.000	0.274
2008	0.184	0.094	0.027	0.042	0.006	0.608	0.059	0.021	0.253	0.089	0.129	0.031	0.002	0.050	0.001	0.299
2009	0.157	0.134	0.026	0.059	0.003	0.698	0.062	0.019	0.254	0.103	0.151	0.030	0.001	0.010	0.012	0.317
2010	0.189	0.098	0.021	0.050	0.010	0.512	0.026	0.016	0.133	0.098	0.150	0.025	0.002	0.031	0.015	0.251
2011	0.194	0.199	0.028	0.049	0.009	0.272	0.258	0.073	0.143	0.110	0.158	0.025	0.008	0.045	0.000	0.291
2012	0.294	0.117	0.032	0.038	0.006	0.253	0.197	0.093	0.115	0.073	0.164	0.021	0.001	0.021	0.005	0.263

Table 2.1.4b—Estimates of seasonal full-selection fishing mortality rates, expressed on an annual time scale (Models 2-3). Sea1=Jan-Feb, Sea2=Mar-Apr, Sea3=May-Jul, Sea4=Aug-Oct, Sea5=Nov-Dec. Rates have been multiplied by relative season length before summing to get total.

	Model 2						Model 3						Model 4					
Year	Sea1	Sea2	Sea3	Sea4	Sea5	Total	Sea1	Sea2	Sea3	Sea4	Sea5	Total	Sea1	Sea2	Sea3	Sea4	Sea5	Total
1977	0.946	0.957	0.665	0.628	0.572	0.735	1.287	1.313	0.977	0.936	0.824	1.049	0.229	0.218	0.131	0.128	0.123	0.159
1978	1.037	0.991	0.669	0.598	0.568	0.749	1.479	1.438	1.031	0.937	0.864	1.122	0.222	0.207	0.127	0.118	0.116	0.152
1979	0.653	0.632	0.433	0.392	0.350	0.479	0.989	0.971	0.700	0.645	0.568	0.758	0.132	0.125	0.080	0.075	0.069	0.093
1980	0.535	0.473	0.295	0.249	0.200	0.337	0.861	0.769	0.504	0.429	0.334	0.561	0.107	0.095	0.058	0.052	0.045	0.069
1981	0.198	0.168	0.182	0.214	0.185	0.191	0.323	0.272	0.303	0.359	0.300	0.315	0.046	0.041	0.045	0.057	0.053	0.049
1982	0.120	0.109	0.119	0.098	0.077	0.105	0.190	0.170	0.189	0.155	0.116	0.166	0.036	0.034	0.038	0.034	0.028	0.034
1983	0.147	0.144	0.128	0.099	0.085	0.119	0.217	0.210	0.190	0.145	0.120	0.175	0.055	0.055	0.048	0.040	0.036	0.047
1984	0.172	0.176	0.147	0.157	0.174	0.163	0.236	0.238	0.207	0.221	0.234	0.225	0.074	0.076	0.061	0.071	0.079	0.071
1985	0.210	0.217	0.161	0.149	0.158	0.175	0.277	0.284	0.224	0.208	0.211	0.237	0.095	0.099	0.069	0.069	0.074	0.079
1986	0.219	0.221	0.147	0.129	0.138	0.165	0.287	0.286	0.202	0.178	0.181	0.220	0.103	0.105	0.066	0.063	0.069	0.078
1987	0.273	0.276	0.132	0.136	0.172	0.187	0.352	0.353	0.175	0.182	0.221	0.244	0.136	0.138	0.062	0.070	0.089	0.094
1988	0.381	0.390	0.193	0.144	0.162	0.240	0.481	0.490	0.252	0.190	0.205	0.306	0.199	0.202	0.094	0.076	0.087	0.124
1989	0.387	0.399	0.185	0.088	0.086	0.214	0.479	0.492	0.236	0.112	0.105	0.267	0.210	0.216	0.095	0.048	0.048	0.115
1990	0.369	0.390	0.219	0.124	0.119	0.232	0.443	0.465	0.271	0.155	0.143	0.281	0.209	0.219	0.115	0.070	0.068	0.129
1991	0.451	0.896	0.264	0.265	0.200	0.390	0.530	1.057	0.327	0.338	0.245	0.471	0.257	0.499	0.134	0.144	0.108	0.214
1992	0.546	0.860	0.418	0.258	0.027	0.408	0.659	1.046	0.535	0.341	0.034	0.509	0.293	0.450	0.199	0.131	0.014	0.209
1993	0.754	0.884	0.108	0.081	0.024	0.324	0.941	1.113	0.140	0.107	0.031	0.409	0.389	0.448	0.051	0.042	0.013	0.165
1994	0.478	1.035	0.101	0.340	0.030	0.367	0.588	1.279	0.127	0.434	0.037	0.458	0.266	0.569	0.052	0.190	0.018	0.203
1995	0.755	1.335	0.106	0.356	0.113	0.482	0.909	1.622	0.133	0.450	0.137	0.591	0.438	0.747	0.055	0.199	0.064	0.272
1996	0.654	1.283	0.196	0.323	0.067	0.464	0.782	1.546	0.246	0.409	0.081	0.565	0.373	0.714	0.103	0.181	0.039	0.259
1997	0.817	1.459	0.211	0.348	0.425	0.590	0.973	1.751	0.265	0.436	0.516	0.715	0.470	0.809	0.109	0.191	0.234	0.327
1998	0.841	1.047	0.176	0.385	0.292	0.504	1.006	1.260	0.222	0.489	0.358	0.615	0.456	0.548	0.086	0.200	0.152	0.264
1999	1.077	1.187	0.169	0.399	0.107	0.537	1.303	1.458	0.219	0.523	0.135	0.668	0.545	0.571	0.075	0.190	0.051	0.261
2000	1.299	0.771	0.079	0.351	0.304	0.503	1.625	0.975	0.104	0.464	0.387	0.640	0.617	0.356	0.035	0.168	0.149	0.238
2001	0.520	0.772	0.093	0.460	0.332	0.409	0.650	0.967	0.121	0.594	0.416	0.518	0.257	0.378	0.044	0.230	0.168	0.202
2002	0.872	0.791	0.115	0.482	0.228	0.464	1.079	0.985	0.149	0.626	0.287	0.585	0.438	0.389	0.054	0.241	0.116	0.231
2003	1.065	0.582	0.096	0.437	0.253	0.450	1.318	0.721	0.124	0.561	0.313	0.563	0.538	0.290	0.046	0.227	0.134	0.229
2004	0.972	0.544	0.121	0.371	0.264	0.420	1.183	0.662	0.152	0.464	0.318	0.515	0.515	0.284	0.061	0.201	0.145	0.223
2005	1.184	0.383	0.101	0.396	0.304	0.436	1.409	0.455	0.124	0.487	0.361	0.524	0.638	0.201	0.051	0.212	0.163	0.233
2006	1.443	0.439	0.098	0.580	0.034	0.489	1.696	0.519	0.121	0.721	0.040	0.586	0.745	0.218	0.046	0.289	0.017	0.247
2007	1.413	0.430	0.157	0.506	0.017	0.476	1.672	0.512	0.195	0.634	0.021	0.575	0.683	0.201	0.069	0.237	0.008	0.225
2008	1.608	0.335	0.103	0.709	0.211	0.562	1.921	0.404	0.129	0.898	0.259	0.687	0.731	0.146	0.043	0.310	0.091	0.250
2009	1.807	0.429	0.108	0.743	0.260	0.629	2.207	0.530	0.138	0.963	0.327	0.786	0.748	0.169	0.041	0.295	0.104	0.254
2010	1.633	0.279	0.093	0.479	0.261	0.505	2.024	0.347	0.118	0.609	0.319	0.630	0.647	0.109	0.036	0.197	0.110	0.203
2011	1.170	0.906	0.244	0.570	0.279	0.596	1.406	1.088	0.301	0.701	0.332	0.722	0.487	0.362	0.093	0.225	0.112	0.240
2012	1.411	0.670	0.297	0.428	0.204	0.562	1.648	0.780	0.356	0.510	0.232	0.660	0.552	0.253	0.108	0.164	0.079	0.215

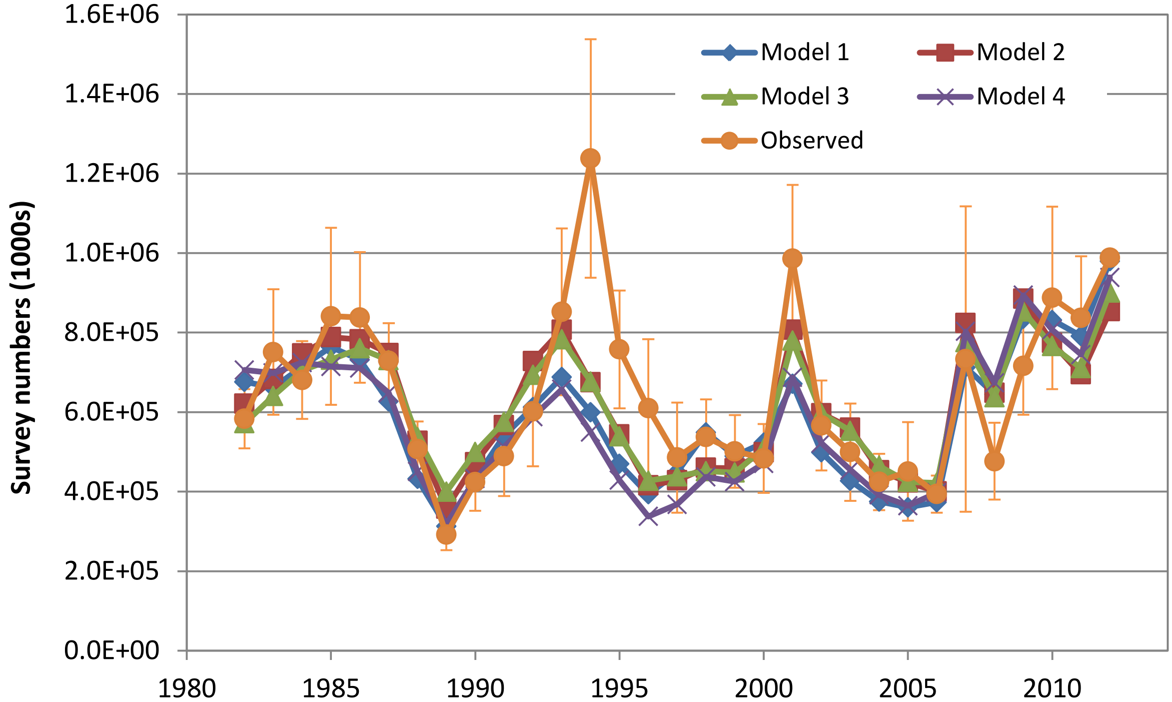

Figure 2.1.1—Fit of the four models to the trawl survey abundance time series.

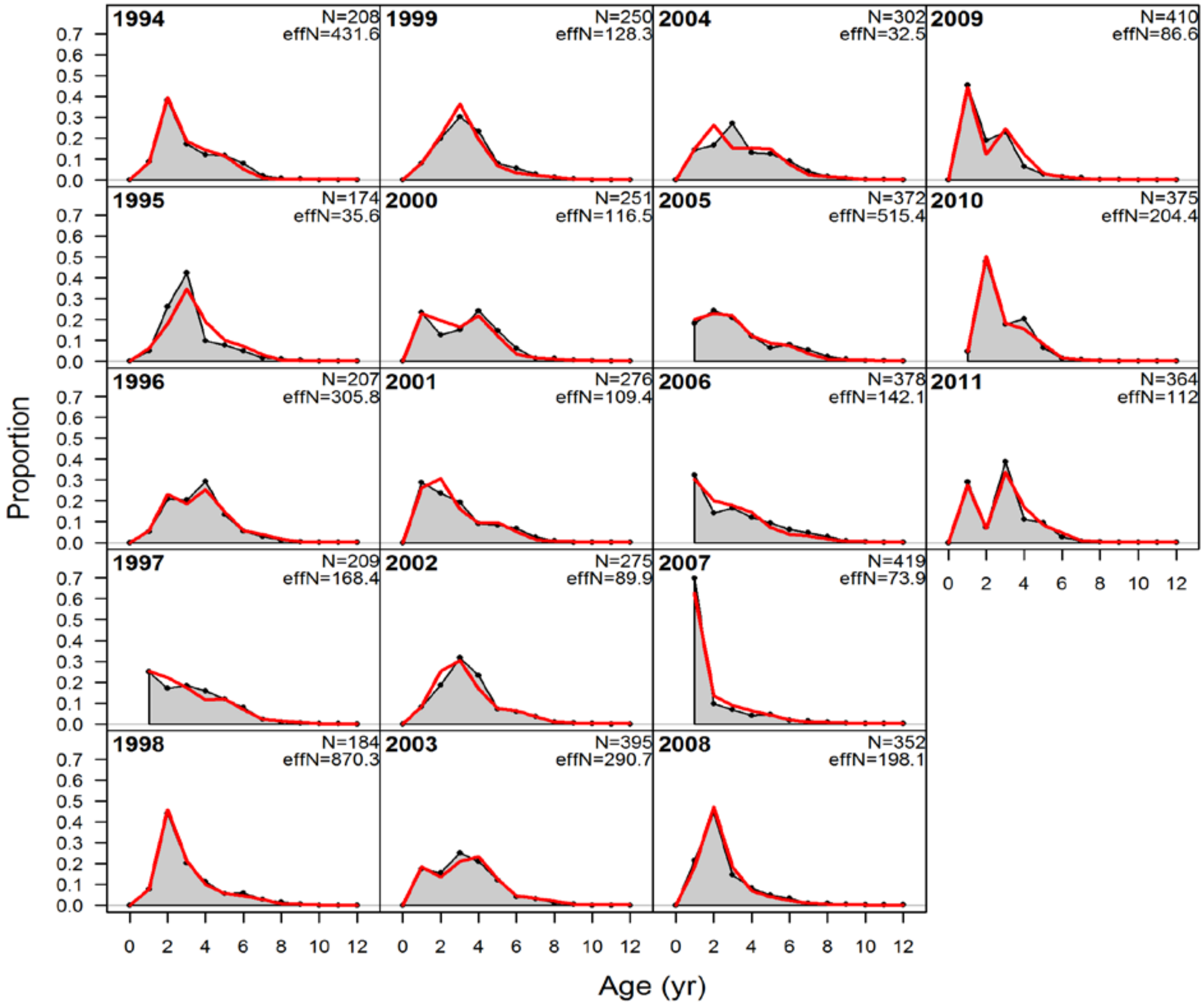

Figure 2.1.2a—Model 1's fit to the survey age composition data (grey = observed, red = estimated).

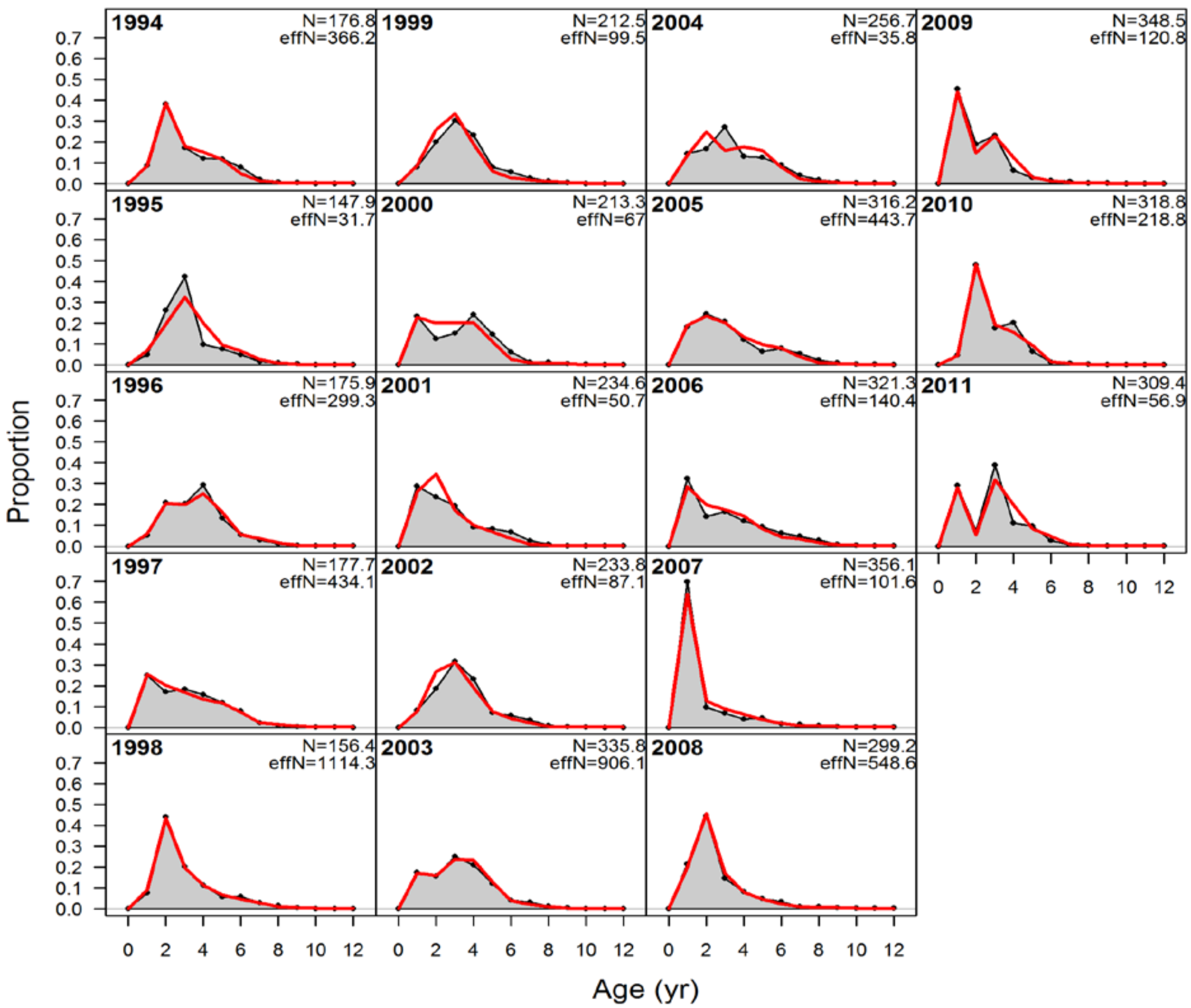

Figure 2.1.2b—Model 2's fit to the survey age composition data (grey = observed, red = estimated).

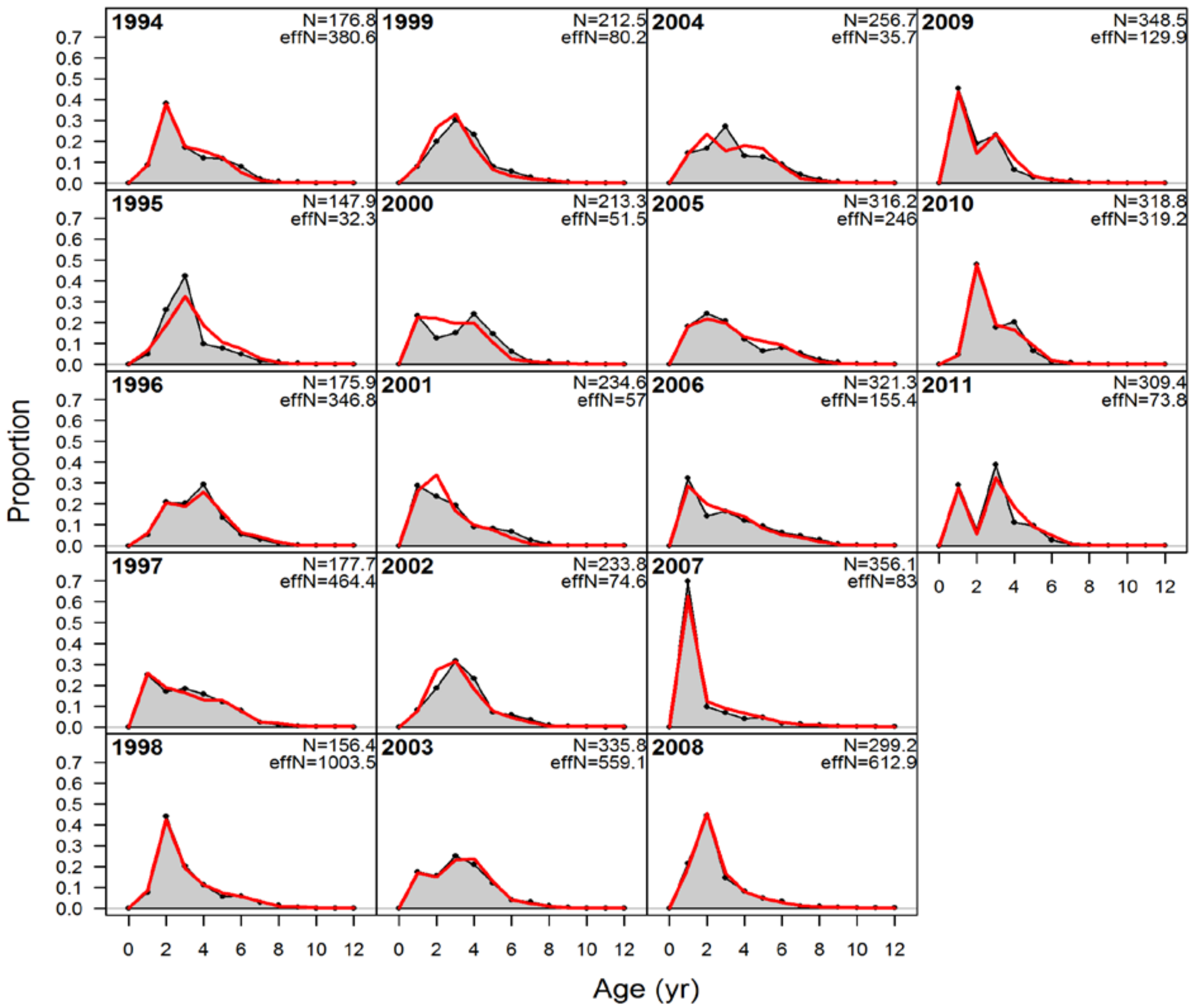

Figure 2.1.2c—Model 3's fit to the survey age composition data (grey = observed, red = estimated).

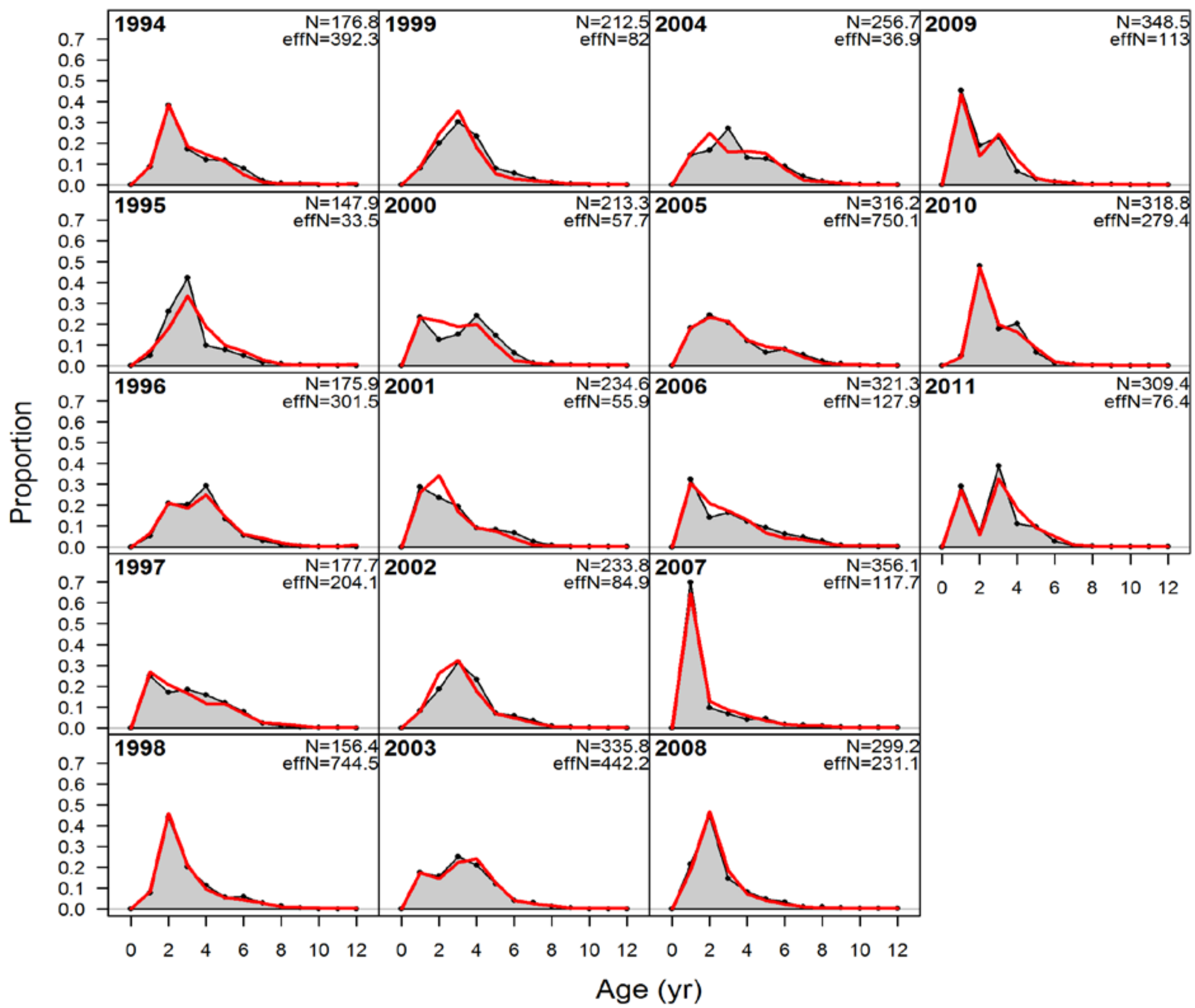

Figure 2.1.2d—Model 4's fit to the survey age composition data (grey = observed, red = estimated).

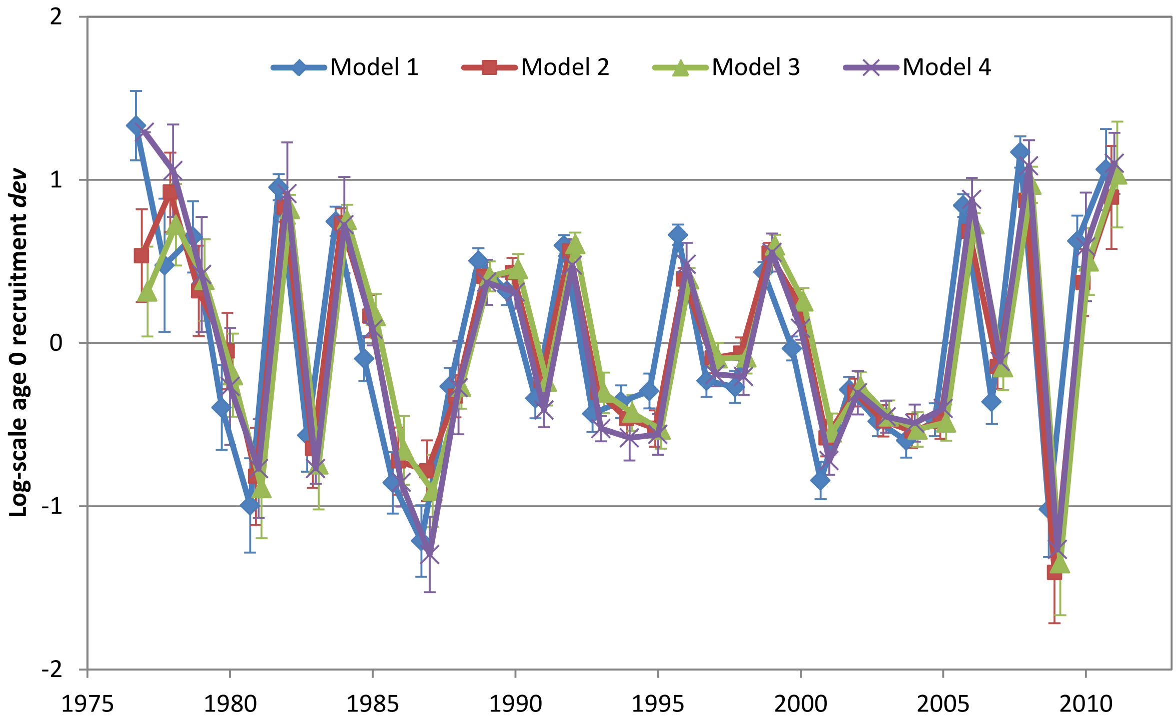

Figure 2.1.3—Time series of log recruitment deviations estimated by the four models. Horizontal axis values have been offset slightly between models to improve visibility.

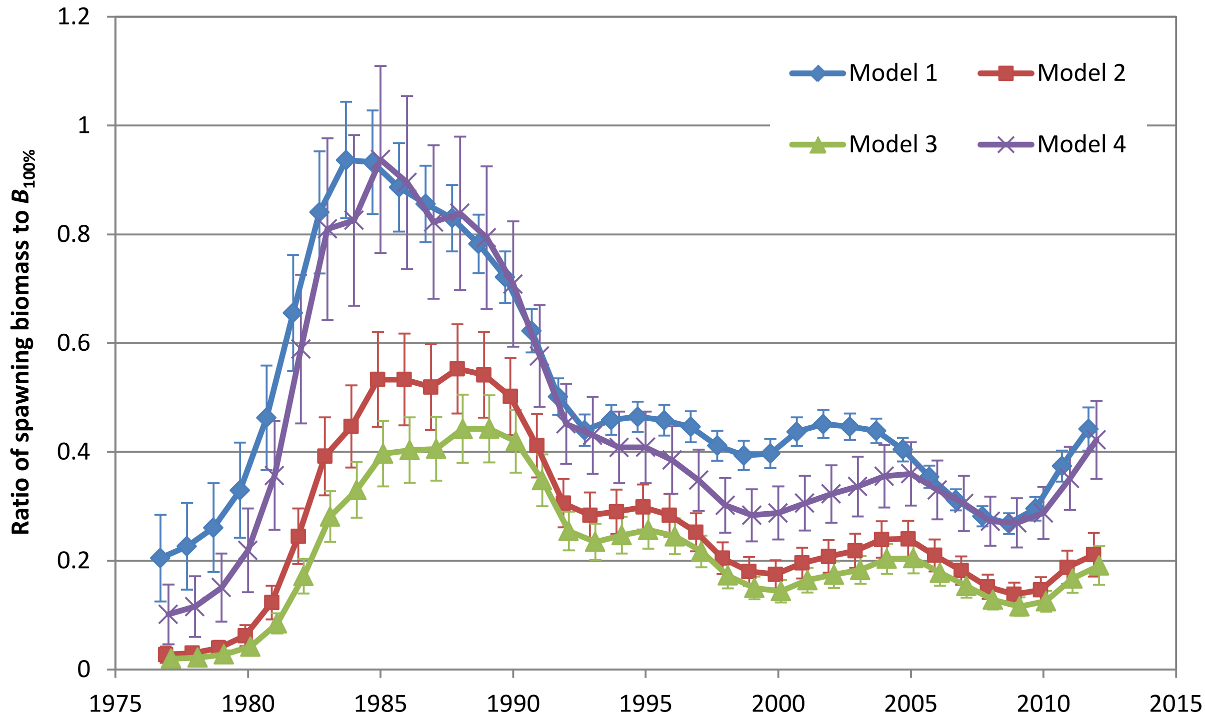

Figure 2.1.4—Time series of spawning biomass relative to $B_{100\%}$ as estimated by the four models.

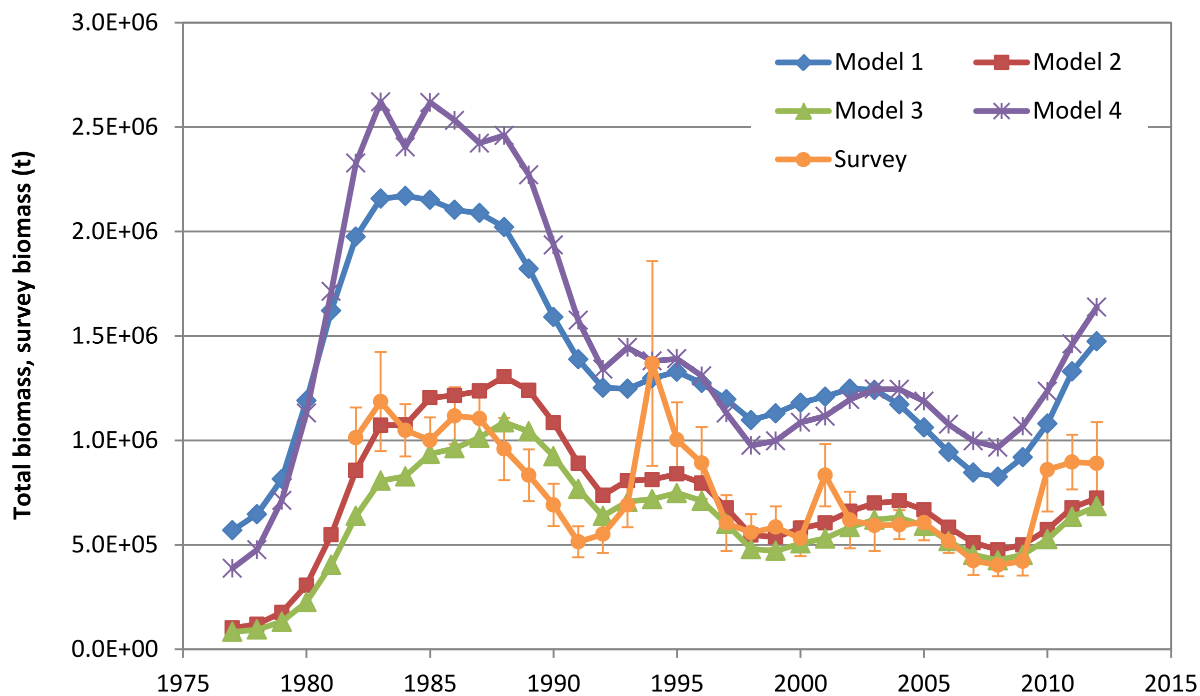

Figure 2.1.5— Time series of total (age 0+) biomass as estimated by the four models. Survey biomass is shown for comparison.

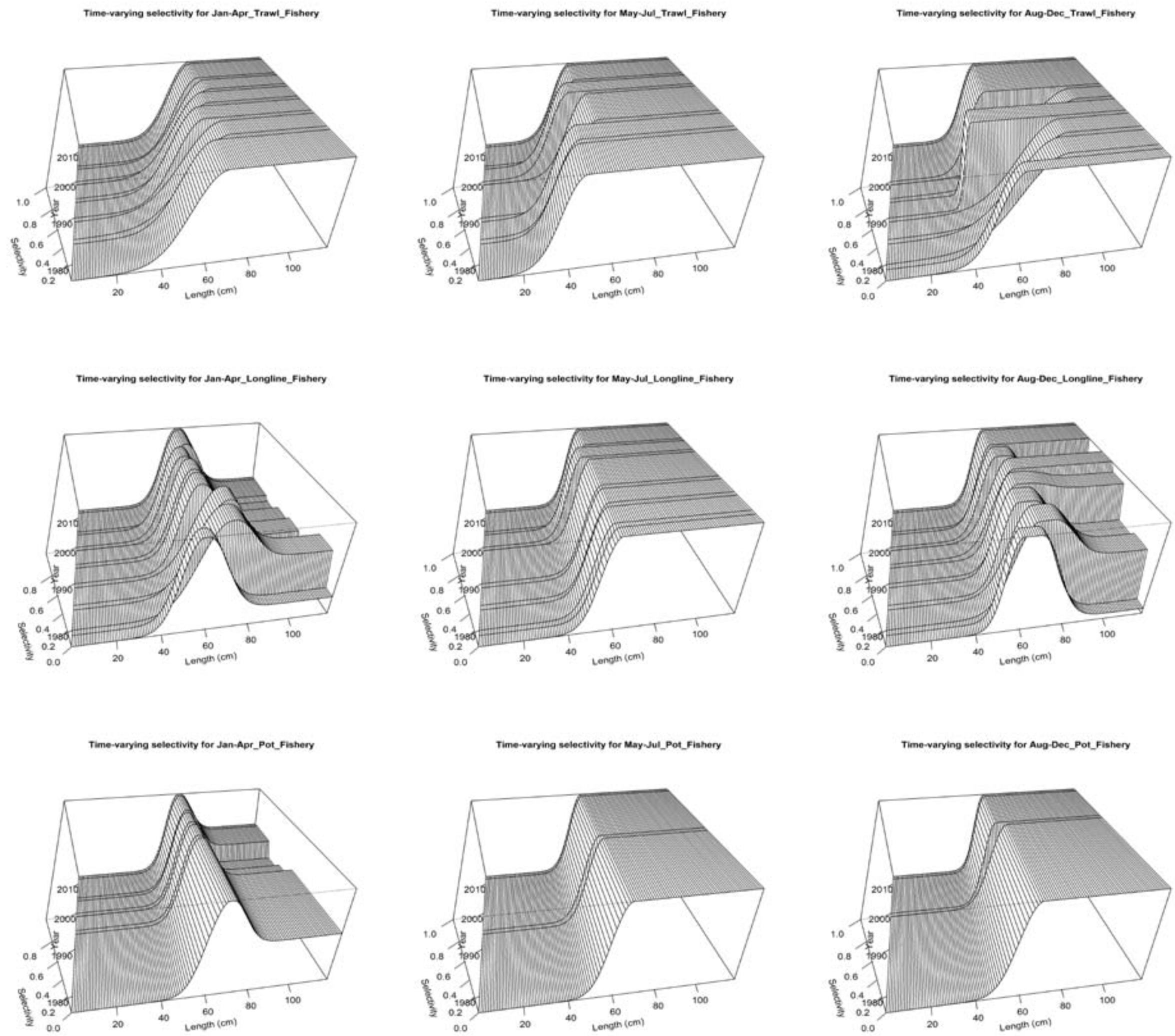

Figure 2.1.6a—Fishery selectivity at length (cm) as estimated by Model 1. Rows represent gear types (trawl, longline, and pot, respectively), and columns represent seasons (Jan-Apr, May-Jul, and Aug-Dec, respectively).

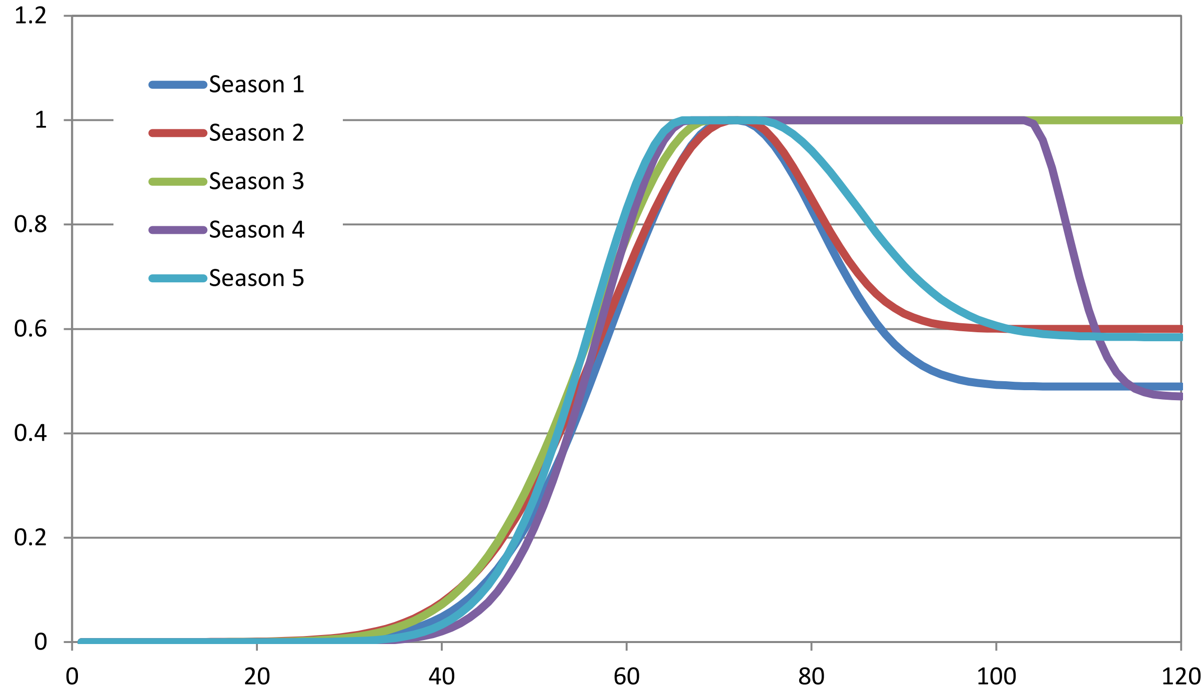

Figure 2.1.6b—Fishery selectivity at length (cm) as estimated by Model 2.

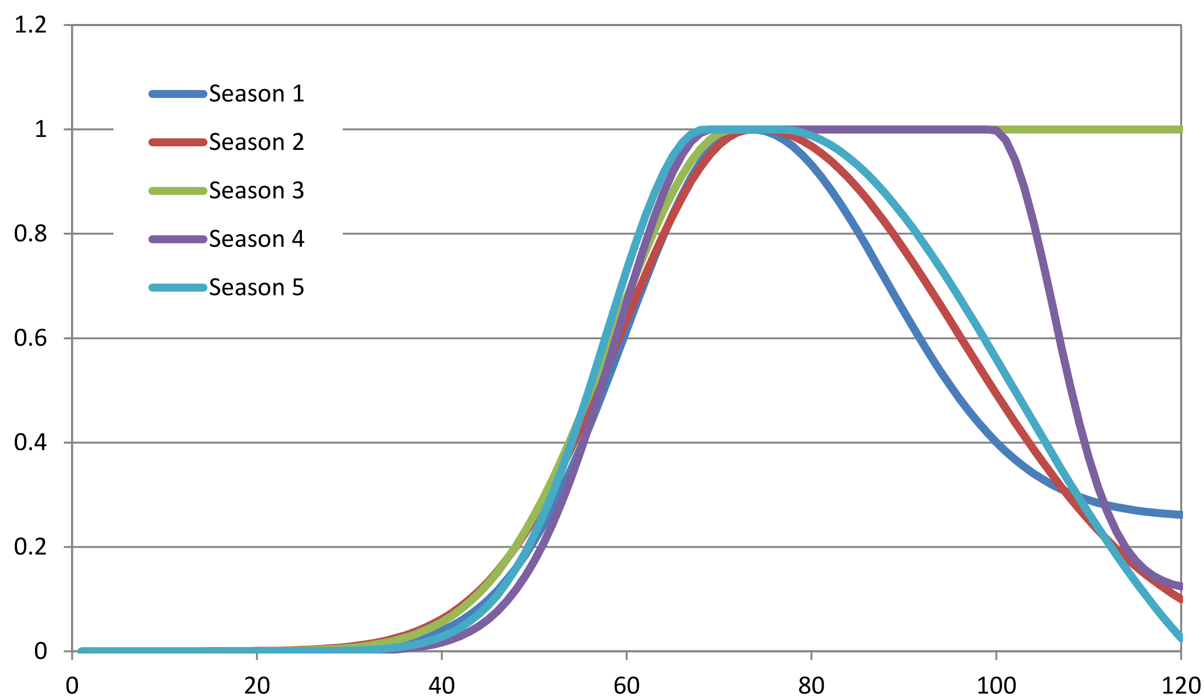

Figure 2.1.6c—Fishery selectivity at length (cm) as estimated by Model 3.

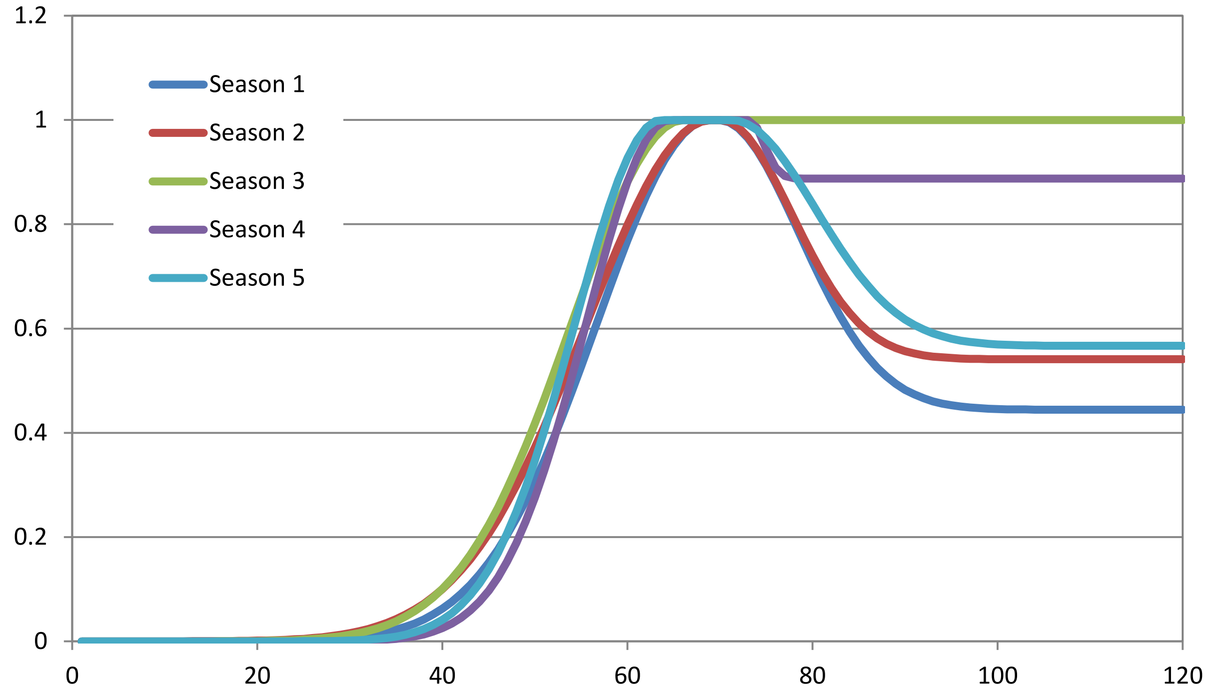

Figure 2.1.6d—Fishery selectivity at length (cm) as estimated by Model 4.

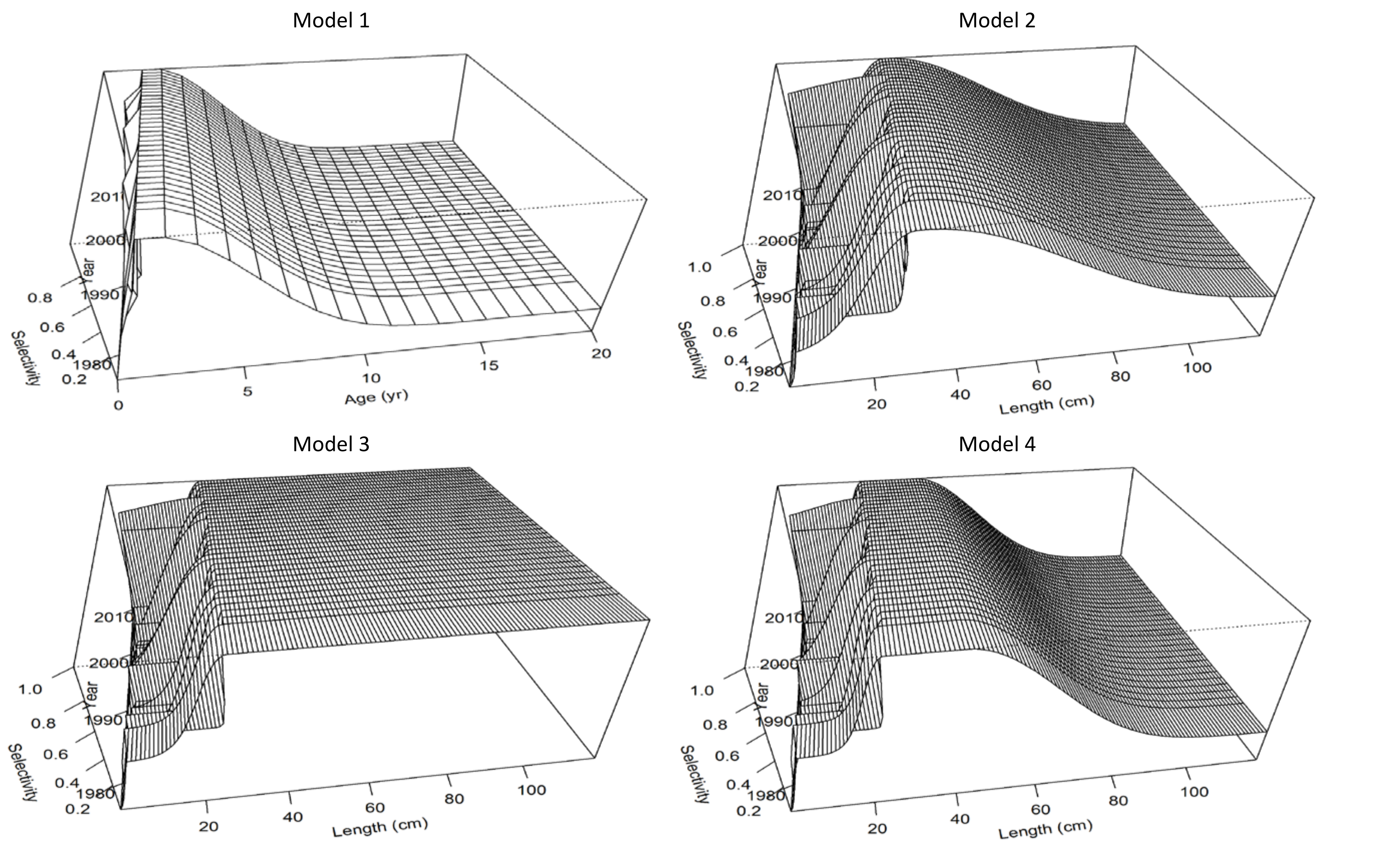

Figure 2.1.7—Survey selectivity at age (Model 1) and length (Models 2-4).